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WHAT WE DO KNOW ABOUT RACE

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THE physical characteristics used by anthropologists to classify people racially have, so far as we know, practically no significance for cultural achievement. We can not validly say that skin color, hair form and other racial differences, of themselves and without reference to the attention paid to them, are of any consequence in human behavior. If we were to take no notice of the shape of the nose, we could not say that people with noses of one shape would not be just as well prepared to run governments or to write books as people with noses of another shape. We have no reason to conclude that the lips of Negroes are not as good instruments as other kinds of lips for speaking beautiful French or perfect English, as well as excellent Bantu. The brains of Chinese, African and North European are boxed in bony containers that differ somewhat in their characteristic shapes, but we have no real evidence that, on the average, the brains contained in the skulls of representatives of one of these racial groups are better organs for thinking than those occupying the skulls of representatives of the other groups.

What we do know to be important about race is known about the races that people see and recognize, or believe to exist. Physical anthropologists are concerned with race as a biological phenomenon. In this paper we are concerned with race as a social phenomenon. We might speak of the "socially supposed races." Such races have a reality, too, but it is different from the reality of biological races. If people took special notice of red automobiles, were attracted to or repelled by the color of red automobiles, and believed that the redness of automobiles was connected inseparably with their mechanical effectiveness, then red automobiles would constitute a real and important category. It is something like that with the socially supposed races. The real differences among biologically different groups may have little consequences for the affairs of men. The believed-in differences, and the visible differences of which notice is taken, do have consequence for the affairs of men. This is what we know about race. It is on the level of habit, custom, sentiment and attitude that race, as a matter of practical significance, is to be understood. Race is, so to speak, a human invention.

The biological differences which enable us to classify the human species into races are superficial differences. There are few racial differences deep inside our bodies. Racial differences are mostly in the outermost layer. This fact is important for the social significance of race, because, being in the outermost layer, racial differences are easily visible. It is skin color, hair form, the shape of the nose, the lips and the eyelids that enter into our awareness and become con-

nected with attitudes and judgments. The relative flatness of the shin bone has been used as a criterion in the biological classification of races. But there is no prejudice against flat-shinned races as such, because nobody, except perhaps a few anthropologists, know they exist. The visible racial characteristics constitute a marker, a label, for all to read. When the label has not been put there by nature, and if the identification of the group has become important in the thinking of people, there is a disposition to exaggerate it or even to manufacture it. When one drop of African blood makes a Negro, it may be believed advisable to look at the fingernails or the whites of the eyes of an individual to discover to which racial category he belongs. The anthropologists tell us that the Jews are not a race. They are not a biological race because the people known as Jews are not enough like each other and are too much like other people to be distinguishable from them. But as people act with reference to Jews, and to some extent connect the attitudes they have about them with real or imagined biological characteristics, they are a socially supposed race. As such, they lack a clear and consistent natural label. The Nazis require them to wear yellow arm bands or the Star of David. A cartoon stereotype of the Jew has comparable effect.

It is the association of some such label with cultural differences and in combination with real or imagined biological differences that brings about a socially supposed race. The observable physical difference is alone not enough. Red-haired people are not collectively noticed and judged any more than are red automobiles. They do not constitute a cultural group. But Negroes are, or have been, a cultural group, and the same is true of Chinese and Japanese, Italians, Jews and Swedes and, indeed, of lawyers, gangsters and professors. These are in varying degrees cultural groups, but in the cases of those named toward the end of this list there is little or no physical label, and much less disposition to identify the cultural difference with real or supposed biological difference. So lawyers, gangsters and professors, whatever else they may be, are not socially supposed races.

In the Negro, the Chinese, the Jew and the White Gentile, the apparent marks of difference become identified with the sentiments and collective judgments that are held about these groups. In the first place these visible markers serve to assign a marked individual to the class to which others feel he belongs or to which he feels he belongs. If members of my group look down upon Negroes, then any person with a black skin is recognized as one to be looked down upon. In the second place the racial labels and the biological differences which are believed to lie in, or be connected with, these labels become the reasons and the supposed proofs of the sentiments and judgments borne toward the marked group. When the rise of the cotton industry induced Southern leaders before the Civil War to stop apologizing for slavery and to begin defending it, it was asserted that the Negro lacked the native intelligence to be more than a slave. It was said that the low skull of the Negro pressed upon his brain and prevented him from becoming intelligent.

It was not, of course, the Negro's skull that pressed upon him. It was slavery and ignorance that pressed upon him. But the skull got the blame. The skulls always do. When people have prejudices it is convenient to support them by referring to the will of God or the wisdom of science. The latter is as innocent as the former. The beliefs of people about the physical features of race become a sort of false science. Or we might call them a modern mythology. We believe many things about people who are dif-

ferent from ourselves, many of which are not true. It is not now widely believed in this country that Jews perform ritual murder; the belief that they control the present Federal Government or American business is more commonly encountered. In so far as the Jews are thought of racially, these are beliefs as to race, and so relevant to our discussion.

We now review some of the things that we do know to be important about race. We do know that the cultural differences between groups come to be associated with noticed and imagined physical differences and that sometimes the latter are regarded as the explanation of the former. We learn that this happens and something about how it happens from the history of race relations. The racial explanation of cultural differences has great antiquity and has followed a varying career. In a great many societies where groups looking and acting differently have dwelt together, the differences between them and the kinds of relationships established between them have been explained racially. They are also often commonly justified racially. Greek writers offered a justification in racial terms for the subordination of helots to Athenian citizens. Negro slavery and discrimination against Negroes have been regularly supported by similar argument. The doctrine of a master race, capable of ruling and of creation, as contrasted with lesser breeds, such as Poles and Jews, capable only by being ruled and of imitating and obeying, was developed by a number of nineteenth-century writers. By the Nazis it has been elevated to a cardinal dogma and a principle of statecraft. At present, in this country, the Japanese, who used to be regarded as a wonderful little people, are being radically reinterpreted. Our enemies, they tend also to be set away so far from us racially that it seems as if now they had connection with us hardly humanly at all but only as co-members of the Animal Kingdom.

We are saying that the social significance of race, which is its only practical significance, is a product of history. It results from the interaction of human nature with situations of group difference and group relationship. It is not always the same. It does not even always exist.

For the small child there is, characteristically, no significance in race. There is surely no instinct of racial prejudice or of racial recognition. Children brought up in societies where there are racial prejudices ordinarily begin to share them—or perhaps to rebel against them—at the age when self-consciousness begins. In the first years they exhibit no special sort of behavior toward representatives of other races. They may not even pay much attention to the physical differences. A small White child drawing a picture of the Negro cook in the kitchen, may run into the kitchen to see whether her black friend's eyes are blue or brown. It is clear that attitudes about racial groups have to be learned.

When racial groups come into contact with each other for the first time, it does not always follow that they at once dislike each other. Certainly, under such circumstances, they do not at once pronounce judgment as to the worth or character of each other. The white skin of the European was interesting to the Indian and to the African when first seen. It drew the native to look further into these odd-looking invaders. In some cases the appearance of the newcomer was found to be fearful, and the native fled. Physical difference, within limits, attracts, else the exotic would not be appreciated. The first Negroes brought to Europe by White explorers of Africa were welcomed into intimate household association with aristocratic Englishmen; they were interesting oddities. It

took time for the attitude of the North European toward the black man to develop its characteristic form.

The dependence of racial attitudes upon historical events is likewise shown by the varying course of these changing attitudes with regard to any one racial group. The American Indian has passed through an almost complete cycle of collective judgment: he has been the Noble Red Man, that "varmint," good only when dead, and that appreciated and interesting fellow-American whose blood in one's veins is considered desirable rather than otherwise. I have mentioned the case of the Japanese, the vermin of the present year. It is humbling to a lesser student of race relations to read what one of our greatest sociologists and students of race relations wrote about the Japanese in 1905: "It is indeed probable that in the event of a successful struggle with Russia, little will remain of prejudice against [the Japanese] this smallish, yellow people, or of impediment to social and matrimonial, as well as political and commercial, association with it."[1]

Let it be said again that what we do know about race is that it is significant as account is taken of it at any time and place, and that the significance changes as the time and the place change. In some interracial situations peoples come together freshly; neither has a traditional view of the other; then the character of race relations will be determined largely by immediate circumstances. So it was that some Indian tribes welcomed the White man and regarded him favorably; others sought to destroy him. In such a situation the whole difference could be determined by one gift or one bullet. On the other hand, some interracial situations are the product of long histories, and new events can only modify, one way or the other, the character of those relations. The situation of the Jew is of this sort. He has been so long an international scapegoat that in any new situation that requires a scapegoat he is likely to be the unfortunate candidate.

It follows that the factor of race—the visible marker with its assumed implications as to inherent difference—gets itself attached to groups that are separated or segregated or stigmatized. As people think and feel themselves different from, or better than, other people, and there is a racial marker, so there arises a race-relations problem. In the case of the Chinese on the Pacific Coast, in the early days of anti-Asiatic sentiment, there was an association of a racial marker with an economically conflicting cultural group. The Japanese today is at once the enemy with whom we have come to closest grips and also the wearer of a face notably different from our own. The influence of the racial marker may be so strong as to overcome even the knowledge gained by personal acquaintance with members of the racial group. To cite one example I mention the situation of many young American citizens of Japanese descent who are today confined in relocation centers. In one of these centers an American of, I think, Swedish descent was employed as a garage foreman in charge of six or seven mechanics. Finally he gave up the job after trying for weeks to be happy in it. "It's no use," he said; I look at them and I can't help thinking of them as Japs." He meant, of course, as our Japanese enemies on the other side of the lines on Guadalcanal. Yet his mechanics were boys born and brought up in Oakland and Los Angeles and educated in our schools. Had they looked like his own sons, the foreman would have got along with them, and would, probably, have forgotten the fact that they had enemy-alien parents.

The effectiveness of race as an indicator of the relations between groups is

[1] W. I. Thomas, *American Journal of Sociology*, 91: 608–9.

probably greatest where it indicates higher and lower social status. When there are castes within a society, and the one caste is racially different from the others, then race is of greatest social consequence. The whole system depends on it. Our Old South is the most familiar example of this situation. In that society the fundamental castes are social castes. The significance of race is to identify the members of the two castes and to keep the one below the other. Negro and White may have close personal relations. White and Negro may be linked in intimate sympathetic association. A White child caresses his Negro mammy. But the black skin, the conception of one drop of Negro blood, and a great many secondary indicators of the subordinated racial group serve to keep the castes sharply separated in terms of "aboveness" and "belowness." It is all right for Negro and White to be close together provided that the one is, without doubt, below the other. Hence come such Southern usages as the separation of Whites and Blacks at a lunch counter by a single symbolic vertical brass pole, or the practice of certain Southern banks to send out monthly statements of account to all White customers with the name at the head of the sheet prefixed with "Mr." or "Mrs.," while the bank statements of Negro customers are made up without this designation.

In the North, on the other hand, and to a growing extent in the South, racial markers are not so clearly arrangements for the maintenance of caste lines. Negroes have education and enter the professions, and the intimate families and small communities of both Negroes and Whites give way to looser and more impersonal communities. So the Negro and the White drift apart from each other as the Negro to some degree gets out from under the White. The Negro and the White do not look directly up and directly down at each other; they come, almost, to look across at each other. Race is still important, but it serves to mark separation more and subordination less. So it is sometimes said that there is more race prejudice in the North than in the South. By this is meant that in the North the Negro is kept away from the White by the factor of race. Human relations between the two groups are restricted by the difference of color. A man is prejudged as unworthy, or as merely inappropriate, to associate with because he is a Negro. In the Old South the individual Negro was treated humanly just because he did not compete with the White for status. But when and if, in the South, he did or does challenge the status position of the White man, the response of the White man was or is correspondingly vigorous.

It is an understatement to admit that these few remarks about our own outstanding race-relations situation are inadequate to the topic. They are a few syllables muttered before a sphinx. Nevertheless it is easier to say something responsible, even though far inadequate, about Negro-White relations than it is to describe anti-Semitism under the heading, "What We Do Know About Race." What we do know about race in connection with the Jew is that race has played only one part in a long drama with many other actors. Antipathy against the Jews is ancient; the identification of the Jews in racial terms, and the justification of anti-Judaism by reference to supposed biological fact, has entered into the problem at some times and in some places. To see that fact is itself helpful in dealing with the problem.

Antipathy against the Jew existed in the Roman Empire before Christianity; therefore the antithesis between Christian and Jew is not a necessary condition of anti-Judaism. In the Middle Ages there were important economic fac-

tors in the position of the Jew as trader and money-lender; and the religious justification for anti-Judaism was very great. Indeed, it is only with the decline of religious differences as the principal factors dividing man from his brother that in modern times the case against the Jew has been stated as a matter of race. It was in large part the students of language who gave impetus to the idea. They imagined a homogeneous Aryan people, to be thought of in contrast with the Semitic peoples. This provided a basis for the recent racial nonsense about Aryan and Jew. The idea has its geography as well as its history. It was a German who in 1870 wrote that "civilization will overcome the antipathy against the Israelite who merely professes another religion, but never against the racially different Jew," and it has been chiefly Germans who have spread the doctrine of racial difference between Jew and Gentile—especially the so-called Aryan Gentile. In old Russia antipathy against the Jew rested much more on difference of religion, custom and occupation than it did upon race. Perhaps this is one reason why, under the Soviet régime, when religion was removed or subordinated as a difference between men, and the social doctrine called for economic leveling, anti-Judaism and indeed racial prejudices of all sorts have been so much reduced.

At any rate the difference between the case of the Negro and that of the Jew is apparent. The conventional antipathies against the Negro have short historical roots; and the racial factor entered immediately and has always played an important part. The conventional antipathies against the Jew are outgrowths of prejudices of very great antiquity; and in their variations race has played a much smaller and a more local part. The Jew has long been the universal stranger. As a representative of his traditional religion, he has also been a convenient adversary for militant Christians; and, fairly recently he became, so to speak, a race. It is grim humor to say that the change in status is not a promotion. When one thinks of the massacre of St. Bartholomew and the excesses of the Reign of Terror, one remembers that man may do his worst against man in the name of religion or in the name of economic and political liberty. Yet there is something about the allegation of racial differences that gives a powerful impetus to prejudice. If it is felt that the differences lie in biological nature, then the firing squad and the concentration camp find a terrible false justification as instruments of eugenics.

The cases of the Jew and the Negro, different as they are, have points of resemblance which suggest another item of knowledge that we do have about race. In the case of both Negro and Jew the two different racial groups, or the two different groups thought of as different racially, meet within the confines of our nation. Moreover, they meet within the confines of nations other than ours. In neither case do we find all Negroes in one national state, or all Jews, or all White Gentiles. This fact is no doubt connected with the fact that there is a Negro problem and that we have anti-Semitism. Race relations are most difficult when the representatives of the racial groups meet within a single state and within many states.

This might be stated in terms of racial frontiers. Where racial frontiers correspond with national frontiers and with natural geographic barriers, interracial problems are simplest. Then diplomatic representatives can act for each group, communications can be controlled, and adjustments can be made without much friction. When Japan was opened to the Western world by Perry, the Pacific Ocean marked the frontier between the two racial groups, and the relations of

the two peoples were managed by diplomacy without conflict.

But Japanese came to this country, and Americans went to Japan. The frontiers between the two racial groups came to fall within the respective countries. Now formal representation between governments could no longer speak for the racial groups. Individual Japanese knew individual Americans, and the relations between the two groups were complicated by personal relations as well as by business relations. Especially does the racial frontier become difficult and dangerous where problems of status rise to prominence. The Negro problem was simple when first-generation Africans were concerned, for such Negroes had no part in the struggle for status. It is the changes which take place, or threaten to take place, in the status of the Negro in our society which make the problem acute. It was when Japanese settled in our country, when Japanese having lived here returned to Japan, and when the number of Caucasians in Japan increased that the Oriental-Occidental problem became complicated with matters of status, and so became grave. The anti-Asiatic exclusion and anti-citizenship laws were legislative expressions of a disposition on the part of our people to draw a frontier within a country shared now by Orientals as well as Occidentals. But the racial frontier drawn by custom or law within a state has always to be defended, and defense of it involves conflict and often bitterness.

The apparently irreversible course of civilization is continually complicating the racial frontiers. Populations increase at unequal rates. Industrial development expands from centers of beginning and overflows marginal areas. Political growth is likewise expansive and takes the various forms of imperialism and colonialism. All these events tend to break down a situation in which the racial frontier is the same as the geographic frontier and the same as the frontier of the state. Races meet within the nation, within the community, even within the family. Racial problems become internal.

As they become internal, they become connected with internal issues. The racial factor, having been merely one of the aspects of difference between independent states, becomes an aspect of differences between political groups. Where representatives of different racial groups share the local community, everyone, in his ordinary daily conduct, approves or challenges the now internal racial frontier. No matter what one thinks of anti-Semitism, one may find himself in an apartment building which excludes Jews, and every day the White man gives tacit assent to discrimination against the Negro. Political parties and political sectarian movements seize upon the racial issue for its power to align men against each other, and the worst and the best of national leaders find themselves involved in racial issues.

As racial problems become internal in many countries, so also they become international. Communications between representatives of the same racial group in distant lands increase, and with it consciousness of race. The problems of the East Indian become matters of concern to the American Negro. The Japanese propagandist appeals to the American Negro, claiming that this is a race war and that in spite of national alignments Harlem and Tokyo are on the same side, the victims of the White man's domination. So it is that the internal racial frontiers of many different countries tend to merge, in the global minds of modern men, into one or a few great racial frontiers. The problem of civil rights for the Negro, the problem of extraterritoriality in China, and the problem of the British in India, problems which once appeared local and separate, now come to be interdependent.

These facts are all illustrations of the generalization offered in the beginning of this article. It is the noticed and the believed-in differences of race that are of consequence to men. Race consciousness, race prejudice and race relations of all kinds are aspects of the peculiar nature of man. It is because men have imaginations, because they develop conventional view-points, because they depend on such symbols as skin color, language, religion or surname as the short and easy guides to the expression of established attitudes that race is one of the principal factors in human affairs. Race is, therefore, a variable that depends upon custom and changes with historical event. Therefore, in turn, it may be darkened by propaganda or it may be clarified by education.

No one is needed to demonstrate that the attitudes men have about race run often against their own interests. The people of this country are determined to win this war. It is clearly to their interest to win it. As clearly it is against their interest to prevent the utilization of our human resources in the most effective way possible. Yet White men stop work in war industries because Negroes are employed to work beside them, and the best man for a wartime position may be passed over because he is a Jew. The Chinese or the Philippine resident of our country may be drafted for service overseas in our American army, but he may not ask to become a naturalized citizen. A Black man may fight for the country he shares with White men, but I do not expect to live long enough to see one do so in the uniform of a United States naval officer.

In the face of facts like these one hesitates to suppose that a mere statement of these matters will remove prejudice. To say that the significance of race may be clarified by education and research is only to say that understanding of the matter may by these means be improved. Education and research with regard to race are increasing. It is not clear that race prejudice is decreasing. From this one may not conclude that education and investigation are to be abandoned, but only that changes in racial attitudes follow from influences which, at the present time at least, are stronger than education and science.

While our attention is upon race prejudice, that form of race relations which most obviously makes for difficulty and for pain in the efforts men exert to live with one another, it may be noted that race prejudice has a curious and a mixed history in its relation to social doctrines that do not depend on race. One might think that a great equalitarian cause would always destroy race prejudice. But apparently such a doctrine does not always do so. There have been cases where a great cause has swept aside inconsistent racial doctrines, and there are cases where such a cause has failed to do so, while yet remaining a great cause. The Mohammedan religion took within it all colors and racial groups, with little discrimination. Perhaps this was because Mohammedanism excluded the non-Moslem from the brotherhood of man. Christianity, on the whole and with conspicuous exceptions, has not been as hard on the non-Christian, but racial discrimination flourishes in so-called Christian countries—indeed, it flourishes especially in Christian countries—and even though churchmen take the lead in movements toward racial equalitarianism, their congregations are not practicing brotherhoods. A Negro Episcopalian and a White Episcopalian may kneel at the same altar in a New York church, although they are not likely to meet at the same dinner table; but Southern Negro Baptists and Southern White Baptists go by separate paths toward God.

Similar statements can be made about democracy. Democracy as a faith in the

common man and as an expression of the doctrine of personal liberty and equality, rather than of property rights, drew many of its early leaders from our Old South. Yet it was the South which modified that conception to exclude almost half its population as unfitted for democracy on racial grounds. Jefferson could believe in an equalitarian democracy because he believed that slavery was passing. When slavery and profits became one thing, the South produced Calhoun to justify slavery and to reduce democracy to something like what it had been two thousand years before in Athens.

The revolution in Russia, on the other hand, greatly reduced racial discrimination in that country. It is notable that equal treatment of races appears in societies where an old structure is broken, and among those members of any society who are least involved in an established social structure. It is the Bohemian, not the Philistine, who admits all races at par. Professional players of popular music, who might be regarded both as artists and as a kind of migratory labor, show little color discrimination. It is the newer and the more heterogeneous C. I. O., and not the established and more homogeneous A. F. of L., that extends a hand of welcome to the Negro. This is the reverse of a proposition about race that we have already made. Where race becomes attached to a social category, the category is made more rigid, more difficult to break through. Correspondingly, where social categories are broken down by revolution or overwhelmed by some more important category, as a religion of brotherhood, race may lose its social importance in whole or in part. In a time of war both aspects of the process are present. In so far as we are insecure and fearful, we tend to fix upon an enemy, and there is some disposition to find that enemy in a racial group. There is an inclination to define the Japanese as enemies, racially. Anti-Semitism has certainly not been eliminated from our country during the course of the war, and the fact that the Germans found their scapegoat in the Jew is no insurance that we are not to make a similar choice. On the other hand, the necessity which this war brings to make explicit our doctrine of democracy emphasizes with new clearness the places in which we do not practice that democracy. How matters will develop out of these inconsistent tendencies in our national life it is not possible safely to predict.

SCIENCE AND CAUSATION

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ALTHOUGH reason, order, intelligibility, and their corollaries form the framework of science, it cannot be said that the doctrines of scientific men always accord with them. Since the introduction of statistical methods for analyzing great masses of data, and the consequent emphasis upon correlation rather than causation, and since the wide and rapid acceptance of "the principle of uncertainty" in physics, a disposition rather antithetical towards logical rigor in science has been noticeable. An impressive recent instance is the presidential address of Dr. Irving Langmuir to the American Association for the Advancement of Science. Dr. Langmuir addressed the association on the subject, "Science, Common Sense and Decency." One of the principal topics in his address was causation. He says of this: "The net result of the modern principles of physics has been to wipe out almost completely the dogma of causation."[1]

Is causation a dogma? It is not such, by any means, in logic or metaphysics. In antiquity it was already under challenge from the Greek sceptics, so again from nominalists in medieval times, while Hume, in the eighteenth century, withdrew whatever might have been supposed to be positive grounds for it. The idea persisted in science, evidently, for Mach thought fit to propose the abandonment of it.[2] If an idea which has been so often repudiated continues to recur, a scientific man will perhaps say it must have a cause. Common sense is even more certain of this. Kant, in the *Critique of Pure Reason,* investigates the question, with the well-known result: causality is an a priori category of understanding; not a law of nature, but a mode of relation, in the mind, by which the mind explains phenomena.

A powerful determination of the mind to apply the causal concept in the way Kant describes may be observed in scientific writings, even when the writer questions causation, as for example, Dr. Langmuir does in his own essay. We find there frequent mention of prediction, probability, laws of chance, and definition. The author even goes so far as to say "we still have to deal with causes and effects"; we "must plan for the future"; and though we "do not believe that definite results will inevitably follow," yet we can proceed by "estimating probabilities."[3] Now, of course, prediction and probability rest on assumption, and the assumption may be fairly regarded as an instance of Kant's category at work. If the term *hypothesis* is more agreeable, it will serve equally well; for it signifies that we are giving to the data before us a certain order and necessity; and this is the same as Kant's meaning. Such order and necessity certainly are not observed by the eye, which only reacts to sensory data. To be sure, we are not obliged to make assumptions or hypotheses; but if we do not make them, we are left to impressions entirely, and prediction does not occur nor does science.

Causation is a concept having a long history and many interpretations. Some of the most ingenious thought has been devoted to this subject. But causation is a metaphysical subject; hence scien-

[1] *Science,* Vol. 97, No. 2505, p. 3. January 1, 1943.

[2] *Science of Mechanics,* English translation, pp. 580 ff. Open Court, 1942.

[3] *Loc. cit.,* p. 6.

tific men, or American scientific men at least, shy away from it. This is truly remarkable. Had the mathematician shrunk from thinking about number, class, relation, etc., or the composer renounced scales and harmony, merely because these are not tangibles, the consequence would be no less remarkable. Is one to infer that the American scientist has an antipathy to reflection about the grounds and import of natural objects; that he does not concern himself about their intelligibility or explanation? Is he first and last an empiricist? I do not insinuate an affirmative answer. To the contrary, if one may judge by scientific writing and teaching, the empirical accounting of a body of data is hardly ever sufficient or final. The scientist does go beyond that—and into metempirical snares. If he does not realize this, it is perhaps because he is so possessed by his projects or his laboratory, and so wedded to the metaphysical presuppositions he has always found convenient, that no occasion for circumspection arises. However, he is by no means unique in this regard. Casual reference to other pursuits than science will easily find him company.

Dr. Langmuir believes that "the principle of uncertainty" has given the quietus to causation so far as the phenomena of the atom are concerned. This is because of the mutual exclusiveness of the experimental determinations of velocity and position in the case of moving atomic particles. But in order to disprove causation either within or without the atom, it would be necessary to show that given events, such as the appearance of a certain particle in a certain position, or at a certain rate of motion, were independent of all possible antecedents and grounds. This, however, is quite beyond our present or prospective reach; even the data and findings of Professors Heisenberg and Bohr, I believe, do not imply so momentous a consequence. (It may indeed be that the findings of these distinguished men merely illustrate, not annul, causation; for if I am not mistaken they show obscuration now of position, now of velocity—and this obscuration is itself the effect of a cause, such as radiation.)

Discussion of the "uncertainty principle" in scientific writings (we may notice that it can hardly be a principle unless certain, that is, unless entailing the paradox of uncertainty certain) is beset by the temptation to allow a radical difference between what used to be called molar and molecular dynamics. But at once this difference vanishes; for the molecular scale submits to statistical accounting, and so does the molar—even the astronomical. Inequalities are said to "average out," and in Dr. Langmuir's paper we read of "unmistakable experimental evidence that these phenomena of the behavior of single atoms depend upon the laws of probability and that they are just as unpredictable in detail as the next throw of a coin."[4] A student of philosophy would observe that anything depending upon the laws of probability is *eo ipso* determinate so far as those laws are indeed laws, hence that the admission of such laws within atomic phenomena is an admission of causal relationship. In much writing about the uses of statistics and probability theory it appears that the concept of causation has been abandoned, if not denied, and has been replaced by correlation. But logical analysis will show this to be a patent misapprehension. To say, for example, that the probability of heads in the throw of a coin is 1 to 2, or the correlation of heads with tails in the long run is 1, is a far different thing from saying that there is no determination whatever as between the two possibilities. Might it not have been 2 to 3 and .666? So long as it is not that, why is it not? The whole affair, as between

[4] *Ibid.*, p. 3.

coin-throwing and the system of nature, would be utterly different from what it is if this were a world of absolute chance. We should then have no certainty of an equality between heads and tails. So long as we do have this equality, or presume to have, it can not be explained by a blank, by the denial, that is, of grounds for it. In other words, if there is probability, there is implied order, or rational ground. Causality is simply a mode, among others, in which this ground is evident.

A slight application of logical analysis may show the presence of causality where not suspected. Suppose any event, *E*. Was it uncaused? Then it arose from nothing. If it arose from nothing, that was the equivalent of the rise of 1 from 0, by magical involution, let us say. At the moment of its occurrence it was at once entity and nonentity. This would be a case in which *E* was not *E;* that is, total self-contradiction. Now it may be that events do come about in this manner —that time is a continuous making, out of what to us before seemed nothing. If such is the case, emergent evolution, vitalism, intuitionism, and possibly mysticism and make-believe have sustained their claims. And if the scientist wishes to know the whereabouts and standing of science under that régime he can find out by consulting the writings of the late ingenious Henri Bergson.

If we can not brook self-contradiction and chaos, we shall have to reject the notion that *E* comes from nothing. But to reject that is to affirm that it came from something, which will have been what is meant, in part at least, by the term *cause*. In short: if the effect, then the cause. This obviously pertains to a congeries of small-scale events, like those in an atom, the same as it does to a sequence of large-scale events in common experience. The whole matter comes to this: either causation or unintelligibility.

Dr. Langmuir admits that causation is able to account for "convergent" events but thinks it lacks bearing on events which he calls divergent ("those in which a single discontinuous event . . . becomes magnified in its effect so that the behavior of the whole aggregate does depend upon something that started from a small beginning"). Examples of divergent events are such as the emission of an alpha particle, or the sudden freezing of water when agitated, though the water, when still, may have remained unfrozen, at a temperature well below freezing.[5] But this distinction between convergent and divergent seems unreal. Any convergent event whatever, for instance the expansion of a body on heating, could be plausibly explained as a divergent event since its antecedents have an indefinite extension; or, conversely, since it is the culmen of a series projected from some uniquely selected origin in the incalculably distant past.

The criterion of large effects from small beginnings, which seems to be the main mark of divergency here, is open to much objection. For instance, there might be no noteworthy effect whatever of the emission of alpha particles, whereas a small boy free with matches might initiate the burning of a whole city. The perceptible track left by an alpha particle in a suitable medium, the devastation left by the burning of a city, —both are cognizable as causal phenomena. We may note that Dr. Langmuir uses the term "effect" in the passage quoted. Is this effect an effect of nothing or is it an effect of something? If the first, it seems unintelligible; if the second, it admits cause, and surrenders the question.

Like many other scientific writers, Dr. Langmuir regards predictability as the test of causation. But the two are hardly so close as that. My inability to predict the advent of a nova or the turn of the market, or the inability of all men to do such, would not affect the causal principle by which these do occur; and

[5] *Ibid.*, pp. 3–4.

on the other hand, my assurance that Sunday will be followed by Monday, is by no means either an index of that event or the same thing as it. Predictability seems to be psychological rather than an ontological category. Retrospection is probably closer to causation than prediction.

According to Dr. Langmuir, logic, too, is undermined along with causation. This is partly because "the law of the uniformity of nature" (as he terms it), which he calls a fundamental postulate of logic, has been overthrown by the "principle of uncertainty." But the student of logic has no dependence on this "law." It is apparently an induction, put forth by Mill, not to justify or aid logic but rather natural science. Prediction, probability, natural law, all depend on it, but not logic. Dr. Langmuir also cites the law of excluded middle (between a term and its contradictory there is no middle ground), observing that it has been affected by the same influences as the uniformity "law." But the student of logic is well aware that the principle of excluded middle still holds in what he calls a two-valued system of reasoning, that is, a system in which a term does or does not have a given predicate, or a proposition is or is not true. Instead of being true or false, a proposition may be impossible or meaningless, and a logic which accommodates such additional categories is called many-valued. This expansion of logic does not invalidate the excluded-middle principle. How could it, except by applying that principle itself, hence acknowledging it? Moreover, the whole question respecting that principle is still *sub judice*. But evidently it is no matter to Dr. Langmuir, who thinks neither the uniformity postulate nor excluded middle has much part in science now. It may be of interest to note, however, that mathematics takes a large part in the progress of science, and that after much fire at the foundations, mathematics still stands on the excluded-middle principle.

Having rejected so much, Dr. Langmuir has little left by which he can explain the phenomena of nature or the achievements of science. Common sense, good judgment, and intuition are the constituents of his epistemology. This is an impressive admission. If these terms are intended in the usual sense, one may feel assured that they omit the greatest part of the intellectual apparatus of modern science; while if they mean more than that, or let us say if they mean what is signified by terms like technology, methodology, and reason, then they reinstate the ideas which they were thought to replace.

Inconsistencies or difficulties such as we see here are easily understood. American education, especially scientific education, pays too little attention to reflection on principles. We are in the pioneering stage, concerned far more with objects and common sense than with systematic understanding. It results that we are often found in serious inconsistency and are indifferent to discoveries and speculations beyond our workaday acquaintance. Dr. Langmuir mentions logic, as I have noted. In logic there exists a large body of recent work which is of the highest importance to those who think. Although this includes a treatise which for penetrataion and intellectual magnificence might be thought entitled to the homage of every mind, and has received it from the acutest minds during the generation since its publication—viz., Whitehead and Russell's *Principia Mathematica*—and although many other works of great brilliance and of late authorship are also found here, it can not be said that scientists, except mathematicians, have paid it much attention. At that, logic no doubt receives more scientific notice than metaphysics or epistemology. Scientific men often affect a dread of metaphysics; and to the major-

ity, no doubt, epistemology is an equal or even greater bogy. It is hard to see how any gain can come from this cavalier attitude. A person can not think without making himself something of an epistemologist, and he can not think about things without becoming a metaphysician. There is only one question in the matter: how far does he think? If he is satisfied to manipulate instruments and read tables, then certainly we have no philosopher (and it is doubtful that we have a scientist, though he may be an excellent mechanic or timekeeper). If, on the other hand, he does think things out, he comes to see that questions about causation, implication, order, fact, meaning, etc., are far from being matters of opinion and indifference. All of them are interconnected, and the domain of science lies full amidst them. The continued disregard of anything so patent, by the educators of scientists, is indefensible. Dr. Langmuir seems to deplore the morality that has issued in the present war. There is good reason for deploring its analogue in education, especially in scientific education, namely, the habit of disregarding the mind and fixing all on bodies and interactions of bodies. Understanding, which is the goal, presumably, of all our inquiries, is dependent in many connections on bodies. But not in all connections. The history of science, not to speak of other spheres, is a profound lesson in the hegemony of the mind. Non-scientific persons, observing this, are sometimes tempted to think that if, during scientific education, reflection, with its grounds, criteria, and ends, were more emphasized in its own right, the problems of science would be more rapidly solved (or dissolved) than they are.

SCIENCE AND THE CONCEPT OF FREEDOM: A TRIBUTE TO GALILEO[1]

By Dr. CHAUNCEY D. LEAKE

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PERHAPS "science" is not a satisfactory word symbol. Like all general terms it has too many connotations. These depend on the background, intelligence and conditioning of the user of the word. Like all word symbols for which there is no specific referent, the idea symbol "science," like the idea symbols "freedom," "justice" or "the state," may have just as many different meanings as there are people to employ these symbols. It matters little if the general idea about the symbol is agreed upon; difference in emotional conditioning to the symbol may produce emotional reactions when the symbol is used, which may make impossible a meeting of minds.[2]

Science is generally misunderstood by the mass of humanity. Freedom as a concept is often confused with licentiousness. We should be careful how to use word and idea symbols, if we wish to have clear understanding of our meaning. Perhaps this is why most intellectual discussions begin with definitions of the terms to be used.

[1] From the symposium on "Natural Philosophy" commemorating the 300th anniversary of Newton's birth and Galileo's death, which was to have been presented at the New York meeting of the American Association for the Advancement of Science.

[2] C. K. Ogden and I. A. Richards, *The Meaning of Meaning*, 5th ed., New York and London, 1938.

Science and Freedom

To intellectual Westerners the term "science" means in general that body of organized knowledge about ourselves and our environment that has been subjected to verification by observation or experiment. By the concept "freedom" intelligent Westerners usually mean *responsible* conduct and discussion unhampered by arbitrary external force or fear of such force—responsible in the sense that it is logically and reasonably determined by the circumstances in the situation.

Of course there is much more to "science" and to "freedom" than these general statements. Science is as much an attitude of mind as a body of organized knowledge. Freedom also is as much an attitude of mind as it is a state of being.

To a great extent science is a method of thinking and a method of procedure for the acquisition of knowledge. The aim, method and spirit of science have been frequently discussed.[3] The aim of science seems to be to know the "truth" about ourselves and our environment. By the often abused idea symbol "truth" a scientist means an objectively demonstrable and intellectually coherent explanation of ourselves and the universe.

The method of science involves rigid self-criticism as one proceeds. This is necessary in order to achieve an objectively demonstrable explanation. One method is mathematical: to build by experimental reasoning within the strict limitations of logical consistency, a coherent ideal system with which some of the details of the universe may be found, on experiment, to correspond. Another way is biological and empirical: by observing and describing as carefully as possible some phenomenon in our environment or in ourselves, and then going on to offer a tentative explanation of it, the validity of which may be tested by experiment, and then confirming or modifying our explanation in accordance with the results of such experiments.

The spirit of science is the key to the problem. It involves the concept of "freedom" in such a way as to imply the impossibility of science without freedom. The spirit of science implies freedom to seek the "truth." The spirit of science implies not only freedom to have and to express any view for which there is rational evidence, but also recognition that knowledge of ourselves and the universe is incomplete and subject to revision, and that there is, therefore, no justifiable compulsion to belief beyond *voluntary* acceptance of demonstrably rational evidence.

The spirit of science implies *responsible* freedom in forming individual judgments, and in expressing them. It refuses to acknowledge the justification of any compulsion to belief that is arbitrary, or that involves in any way anything beyond the voluntary acceptance of what is demonstrable to the senses and reasonably or logically derived therefrom. The spirit of science acknowledges no "authority," except voluntary and uncoerced agreement among reasonably competent scholars on the basis of the objective evidence available.[4]

Galileo and Freedom of Science

We are paying tribute to Galileo Galilei (1564–1642) chiefly because he appears as a leading protagonist in the struggle of science with arbitrary authority. Developing the method of critically controlled observation and experiment, Galileo exemplified, as Castiglioni emphasizes, the free-thinking characteristics of his time. This was the age of Shakespeare, Bacon, Milton, Gilbert and Harvey in England, of Kepler, Cervantes

[3] E. G. Conklin, *The Direction of Human Evolution*, New York, 1921; C. D. Leake, "Science Implies Freedom," in *Studies in the History of Culture*, Philadelphia, 1942.

[4] C. D. Leake, "Religio Scientiae," *The Scientific Monthly*, 52: 166, 1941.

and Descartes. The world was opened to the survey of man. In the year of Galileo's death, Newton was born, destined to expand amazingly his intellectual heritage. The first fruits of science testified abundantly to the strength of the root-stock which had been started two millennia previously by the Greeks and which finally had been pruned of much thorny foliage during the Renaissance.

In his popular demonstrations Galileo showed that sensory perception, uncontrolled by careful reasoning, may lead one into as much error as reasoning uncontrolled by experiment. The threat of Galileo's ideas was quickly realized by that established and arbitrary authority which assumed the power to force men to believe, or at least to say that they believed, what that authority decided they should believe.

In 1616 Galileo was reprimanded by Pope Paul IV for the ideas he had expressed. He was told not to "hold, teach, or defend" the condemned doctrine of Copernicus, whose theory Galileo had tried to reconcile with the accepted traditional cosmology of the church.

In 1630 there was published in Florence the famous *Dialogo dei due Massini Sistemi del Mondo Tolemaico e. Copernicano.* In 1632 this book was banned by Pope Urban VIII for heresy and breach of good faith. Galileo was examined by the Inquisition, was threatened with torture, and was sentenced to imprisonment. By way of penance he was compelled once a week for three years to recite the seven penitential psalms.

On Galileo's death in 1642, his anxious wife, hoping to preserve his good name and position, showed to her confessor what manuscripts remained. It is said that he destroyed them as heretical. Two years later John Milton (1608–1674) wrote his famous "Areopagitica: A Speech for the Liberty of Unlicenc'd Printing." Immediately this eloquent plea for freedom of the pen was condemned by Cromwell and the Parliament of Protestant England. In 1641 in Paris was published the *Meditations* of Rene Descartes (1596–1650). Descartes had modified his writings, on learning of the suppression of Galileo's ideas, and had abandoned a project in confirmation of Copernicus. Subsequently the *Meditations* was placed on the *Index Librorum Prohibitorum,* where it still remains.

Three centuries later we may look back upon much of this as silly. The factors behind the seventeenth century difficulties, however, are still with us and are unreconciled in spite of the many protestations that there is no longer any conflict between religion and science. It is clear that the purposes of religion and science are the same, namely, to know the "truth." The difficulty remains in what constitutes the "truth."

Ethical Significance of Science

Science has a particular, specific and well-defined criterion for "truth." This varies significantly from what is considered to be the "truth" by the churches, which are the custodians of religious ideas, and now by certain governments, which claim supervision of the thought of their peoples. Psychologically conditioned acceptance of such supervision constitutes now the gravest threat to the requisite freedom of science. The freedom of science in seeking the "truth" in accordance with its criteria seems to be as essential a freedom as any of the now famous four. Perhaps it was encompassed by President Roosevelt and Prime Minister Churchill in all their four—freedom of expression, freedom in worship, freedom from want and freedom from fear—since these are so clearly implied in the spirit of science, which proposes that belief and conduct

depend on the logical consequences of our verifiable and always increasing knowledge of ourselves and our environment.

For science has significant ethical consequences. These were suspected by Plato, indicated by Galileo, and now are beginning to be appreciated by an increasing number of English and North American scientific leaders. Edwin Grant Conklin has vigorously supported this concept;[5] George Sarton has devoted his patient life to its exposition;[6] C. Judson Herrick has expounded it;[7] Samuel Holmes has coolly considered it.[8] The Unity of Science movement embraces it, and recently C. H. Waddington has led a brilliant discussion of it.[9] The American Association for the Advancement of Science has even devoted symposia to it.

At one of these sessions there were deliberate consideration and tentative agreement with an objectively realized principle, similar as a natural phenomenon to the gravity principle of Galileo which affords a scientific basis for ethics: The probability of the survival of a relationship between individuals or groups of individuals increases with the extent to which the relationship is mutually satisfying or agreeable, and beneficial or advantageous. This is merely a corollary of the evolutionary principle, but it becomes highly significant in view of the common human desire for satisfaction and the common human ability through the use of the brain to achieve it. The difficulty seems to be that brains vary so greatly!

The recent State Department "White Book," *Peace and War: United States Foreign Policy, 1931–1941*, illustrates international factors involving the operation of this principle. Thoughtful persons may derive pertinent examples from their own personal experiences and from the whole course of human history.

Galileo was persecuted in his attempt to explore, in the freedom of scientific inquiry, the implications of new appreciations of mathematical and physical principles. Not for a long time to come is it to be expected that one may freely and openly investigate in the scientific way the implications of newly realized biological principles, to which we as living organisms must conform. The equanimity of Galileo may serve us well for many centuries as an example, in the predicament which scientists may expect unless freedom of science is included in our world charter. Perhaps we may someday learn that individuals may achieve more as individuals by cooperation than by competition.

[5] E. G. Conklin, *The Scientific Monthly*, 49: 99, 1939.

[6] George Sarton, *An Introduction to the History of Science*, Vol. 1, Baltimore, 1927; *The History of Science and the New Humanism*, Harvard, 1937.

[7] C. J. Herrick, *The Scientific Monthly*, 49: 295, 1939.

[8] S. J. Holmes, *Science*, 90: 117, 1940.

[9] C. H. Waddington, *Science and Ethics*, London, 1942.

NATURE'S BRIDGES

By Dr. RAYMOND E. JANSSEN
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ALLURING, entrancing, mystifying—the sight of a beautifully executed bridge unfailingly captures the imagination of the observer. Whether fashioned of stone by Nature or designed of architectural steel by man, a sturdy bridge seldom fails to arrest one's attention. This may be true, perhaps, because our fancies are at once quickened to an appreciation of the labors which brought the bridge into being. Then, too, a bridge always leads somewhere—often to new horizons and new experiences.

No one can question the importance of bridges in our daily lives. Even our ordinary conversations are colored with frequent references to bridges. We say that if we stay on the bridge, we shall cross the river. How often are we reminded that we should not cross our bridges before we reach them? Or again, we are cautioned not to burn our bridges behind us. When we have triumphed in the face of tremendous odds, we say that we have bridged our difficulties. Bridges thus have come to represent stages in human experience.

Natural bridges, not designed and fashioned by the hands of man, are particularly interesting. They, too, represent stages, not in human experience, but in the orderly progression of an ever-changing world. Our curiosity is at once aroused by the sight of a natural bridge, and we can not refrain from speculating about the mighty forces which brought it into existence.

What is a natural bridge? A geologist would say that such a bridge is a natural stone connection spanning a valley of erosion. Then he might add that a natural arch is similar, but does not span an erosional valley. The distinction is largely technical and not entirely clear to most of us. Perhaps it would be more understandable to say that a natural bridge is one which spans a barrier, providing a natural means of crossing from one side to the other. A natural arch, on the other hand, might be called an opening through a natural barrier, just as an arched doorway affords a passage from one room to another. In other words, we cross upon a bridge, but pass through an archway. The matter of definition is, after all, of little importance. Of interest, primarily, is the manner of origin of these natural features.

Best known of all natural spans in America is the Great Natural Bridge of Virginia. It is more than two hundred feet above the stream which passes under it. This natural bridge is of sufficient size and strength to accommodate an automobile highway. United States Highway Number 11, extending from New York State to New Orleans, crosses upon the natural bridge. The origin of this bridge, composed of limestone, is attributed to the collapse of the roof of an underground cavern. At some time in its history, the stream which passes below flowed through an underground passage at this point. Eventually a long subterranean cavern was developed along the course of the underground stream. The greater portion of the roof of this cavern subsequently collapsed, leaving only a small portion still spanning the former cavern. This remaining span thus became a natural bridge, and the underground stream became a surface stream. Smaller, less celebrated natural bridges, formed in similar ways, are found in other parts of America

where soluble limestone constitutes the bedrock.

Natural bridges may also mark the sites of former waterfalls. Sometimes water which is headed for a plunge over a precipice finds an outlet through cracks in the rock strata behind and below the brink. Such trickles of water make a detour around the waterfall proper and emerge beneath it. In the course of long periods of time this passageway may become enlarged to the extent of diverting all the water. When this happens, the brink of the waterfall becomes a natural bridge with the water flowing beneath it. Such a bridge may be seen along the course of the Kicking Horse River in Yoho National Park, British Columbia.

To appreciate best the manner in which such bridges originate, one should view Trick Falls (also called Double Falls) in Glacier National Park. Trick Falls today represents an intermediate stage in the formation of a natural bridge. In the spring and early summer, when the flow is great, vast quantities of water plunge over the brink in normal fashion. At the same time, one may also see water emerging from openings beneath the falls. But in seasons when the flow is greatly diminished, no water plunges over the falls; all of it is diverted through the lower opening. As this geological process is continued in the future, the opening will be enlarged to the extent of accommodating all the water during all seasons. Trick Falls will then become a true natural bridge.

TRICK FALLS, OR DOUBLE FALLS

IN GLACIER NATIONAL PARK, REPRESENTS AN INTERMEDIATE STAGE IN THE FORMATION OF A NATURAL BRIDGE. MUCH OF THE WATER BYPASSES THE UPPER PORTION OF THE FALLS AND EMERGES FROM THE GROWING OPENING BENEATH.

THE GREAT NATURAL BRIDGE

OF VIRGINIA, 200 FEET HIGH, WAS FORMED BY THE COLLAPSE OF A CAVERN ROOF. A NATIONAL AUTOMOBILE HIGHWAY CROSSES UPON THE SPAN.

Largest and most impressive of all natural bridges are those which have been formed by ordinary stream erosion. The finest known examples of these are located in the remote canyon regions of our arid Southwest. The sandstone in

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SIPAPU, OR AUGUSTA, BRIDGE

ONE OF THREE NATURAL SPANS CONSTITUTING THE NATURAL BRIDGES NATIONAL MONUMENT SITUATED NEAR THE HEAD OF WHITE CANYON IN SAN JUAN COUNTY IN UTAH. IT IS 222 FEET HIGH AND 261 FEET LONG. THE SPAN IS 128 FEET WIDE AND 65 FEET THICK AT THE NARROWEST PART.

which these bridges are cut was originally laid down as unconsolidated sand near sea level and later compacted into massive rock under the weight of subsequent overlying deposits. Eventually the region was elevated far above sea level, becoming a vast plateau. Streams, starting as a consequence of the uplift, began carving valleys across the newly formed plateau as the land was rising. In newly uplifted regions, the valleys are narrow and deep because the energy of the stream is devoted primarily to down-cutting processes. If the uplifting of the land is intermittent or relatively slow, streams are able to widen their valleys as well as deepen them. In the widening processes, the streams develop meandering courses characterized by great curves and loops. If the land is further uplifted after the streams have developed such meandering courses, they must again concentrate on the deepening processes, thereby entrenching their winding channels below the level of the original valley. As a result, deep, circuitous gorges may exist within the depths of old valleys.

In many places the streams have formed great loops which are almost complete circles. Within such loops are long spurs, or peninsulas, of rock which have narrow necks. Since winding streams cut mostly along their outside curves, there is a continuous tendency to narrow the necks from each side by impingement of the turbulent current. In time the stream waters undermine the rock walls, eventually breaking through the narrow necks and taking a short cut through the hole thus formed. The rock remaining above the opening thereby becomes a natural bridge spanning the new course of the stream. Subsequent erosion and low-

Santa Fe Railroad

RAINBOW BRIDGE IN SOUTHERN UTAH, 309 FEET HIGH

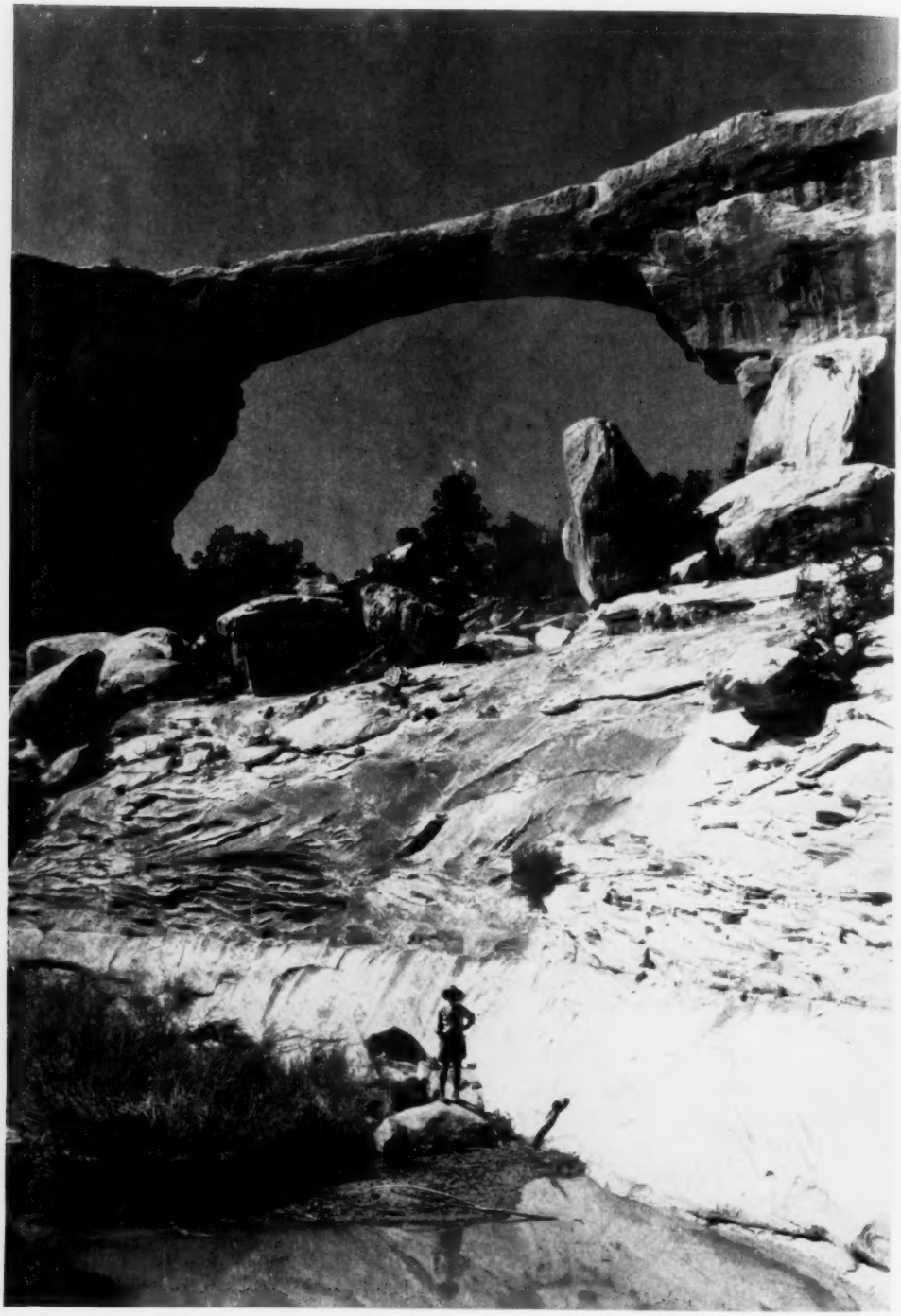
WORLD'S LARGEST KNOWN NATURAL BRIDGE. ITS ARCH WAS FORMED BY A MEANDERING STREAM WHOSE WATERS DASHED AGAINST A MASSIVE SANDSTONE SPUR, EVENTUALLY UNDERCUTTING IT.

ering of the new channels, in some cases, have formed small gorges beneath such bridges.

Foremost among natural bridges formed by ordinary stream erosion is Rainbow Bridge, the largest known natural bridge in the world. It is located within the Piute Indian Reservation in southern Utah, just north of the Arizona boundary. Composed of pinkish sandstone, it presents a symmetrical arch with a curved upper surface, roughly similar to the arch of a rainbow. In the Piute language, the bridge is known as "Barahoini," or rainbow. The Navajos refer to it as "Nonnezoshi," meaning arch, or hole-in-the-rock. Sometimes they call it "Nageelid Nonnezoshi," the rainbow arch.

Rainbow Bridge spans a portion of Bridge Canyon, which extends between the Colorado River and Navajo Mountain. The span measures two hundred and seventy-eight feet from pier to pier, and towers three hundred and nine feet above the stream bed in the gorge below; hence a building having the proportions of our national Capitol at Washington could be erected beneath the bridge with ample room to spare. At its thinnest point the bridge is thirty-three feet wide and forty-two feet thick.

So far as is known, Rainbow Bridge was first seen by white men on August 14, 1909, when a party headed by Professor Byron Cummings, then of the University of Utah, visited the region. He had learned of the existence of the bridge through vague information furnished by a Piute Indian who had seen the bridge and agreed to guide a party to it. The following year, on May 30, 1910, President Taft proclaimed the bridge a national monument. Situated



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OWANCHOMO, OR EDWIN, BRIDGE OF THE NATIONAL MONUMENT GROUP, UTAH

MOST TRULY BRIDGE-LIKE IN DESIGN OF ALL OUR NATURAL SPANS. IT IS 194 FEET LONG AND 108 FEET ABOVE THE STREAM BED. ALTHOUGH ONLY 10 FEET THICK, THE BRIDGE IS 35 FEET WIDE.

in one of the most inaccessible canyon regions of our country, Rainbow Bridge can be reached even now only by pack train, requiring at least three days for the round trip from Navajo Mountain, the terminus of the present automobile highway.

Farther north in this great plateau country is located a group of three natural sandstone bridges of great size and beauty, all within five miles of one another. Situated near the head of White Canyon, in San Juan County, Utah, they comprise the Natural Bridges National Monument, established by President Theodore Roosevelt on April 16, 1908.

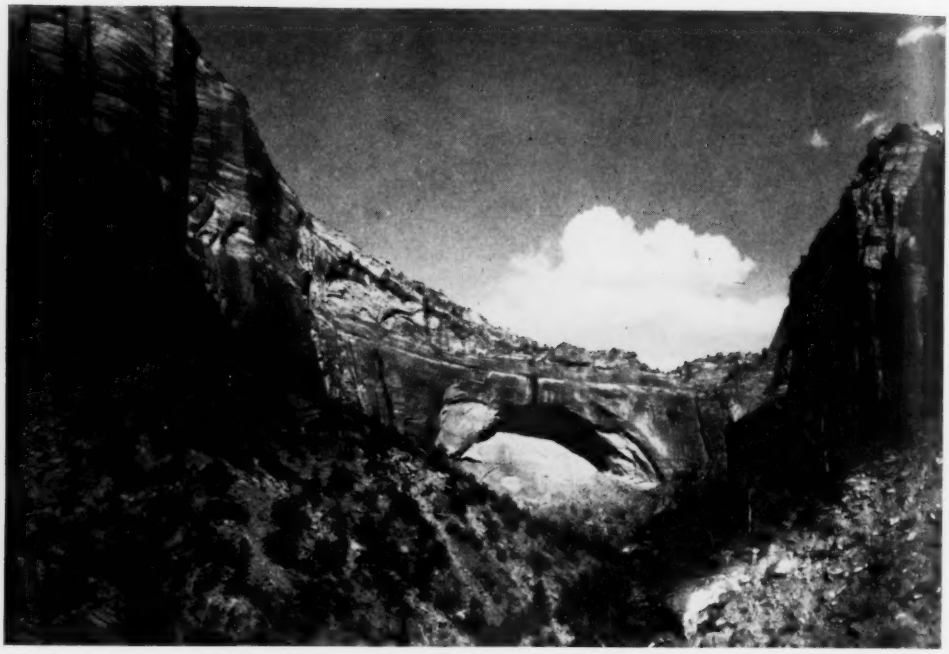
It is not definitely known when these bridges were first seen by white men, although their presence was reported as early as 1883 by a prospector named Cass Hite. They did not become generally known until after March, 1903, when Horace J. Long, a mining engineer, was guided to them by James Scorup, a cattleman. Scorup had caught distant glimpses of them in 1895 while herding cattle on the range. Accounts of Long's visit, carried in the *Century Magazine* of August, 1904, and in *The National Geographic Magazine* of September, 1904, led ultimately to the establishment of the national monument.

Most massive of these three bridges is Kachina Bridge, also known as Carolyn Bridge. The latter name was given it by Long after the name of the mother of James Scorup. Under presidential proclamation, the Indian name was applied because of a symbol carved on one of the buttresses and recognized as that of the Kachina, guardian spirit and symbol of the sacred dancers of the Hopi Indians. This bridge has a span of one hundred and eighty-six feet, and a height of two hundred and five feet above the stream bed. At the top it has a width of forty-

U. S. Dept. of Interior

KACHINA, OR CAROLINE, BRIDGE IN UTAH

ITS INDIAN NAME IS TAKEN FROM THE ANCIENT HOPI SYMBOLS CARVED UPON ITS SIDES. THE SPAN IS MASSIVE, HAVING A THICKNESS OF 107 FEET AND A WIDTH OF 49 FEET AT THE NARROWEST PART.



U. S. Dept. of Interior

THE GREAT ARCH OF ZION, IN ZION NATIONAL PARK, UTAH

EXAMPLE OF AN UNCOMPLETED NATURAL BRIDGE FORMED BY THE EROSIVE ACTION OF A STREAM. THE GREAT SPAN, ONLY PARTLY CUT THROUGH THE ROCK, IS 722 FEET LONG AND 585 FEET HIGH.

nine feet, and a thickness of one hundred and seven feet at its thinnest point.

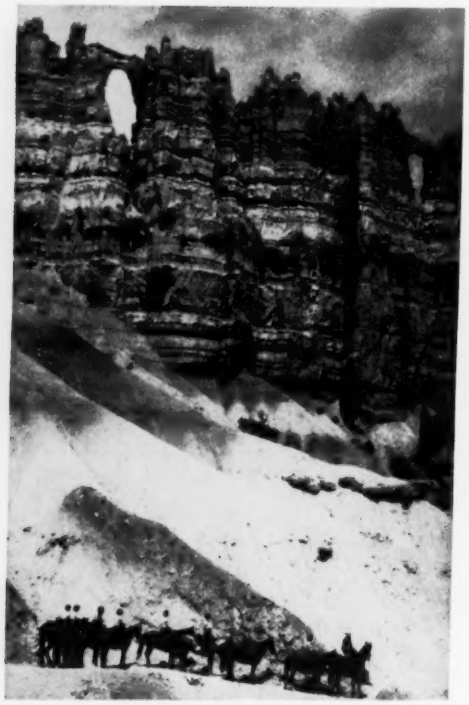
Larger, however, is the Sipapu Bridge, originally called Augusta Bridge in honor of Long's wife. In the Hopi language Sipapu means "portal of life" and refers to a mythical hole, or opening, between the lower and upper worlds through which the Indians believe they enter this life. After death they presumably return again to the lower world through the Sipapu, remaining there for a time before ascending to the heavens to become raingods. The bridge has a span of two hundred and sixty-one feet and towers two hundred and twenty-two feet above the stream bed. The great span is one hundred and twenty-eight feet wide and is sixty-five feet thick at its narrowest point; hence it could easily accommodate a modern superhighway.

Smallest of the three bridges, although massive itself in size, is Owanchomo, or Edwin, Bridge. Originally called Little Bridge by Long, it was renamed Edwin Bridge by an expedition sent out in 1905 by the Salt Lake Commercial Club, and ultimately it was rechristened Owanchomo by President Roosevelt. This name, meaning "flat-rock mound," was derived from the Hopi name of a nearby rock formation. The bridge has a span of one hundred and ninety-four feet, and rises one hundred and eight feet above the stream. Viewed from a distance, it seems incapable of supporting its own weight, since it is only ten feet thick near the central portion. Its width, however, is thirty-five feet, and comparable to that of an ordinary highway. When visited by Long, his party was the first to ride across it on horseback. Owanchomo Bridge is situated in an unnamed canyon near its confluence with Armstrong Canyon, which is, in turn, a tributary of White Canyon.

U. S. Geological Survey

A NATURAL ARCH ALONG THE SEACOAST OF THE GASPÉ PENINSULA

FORMED BY THE POUNDING OF THE WAVES UPON A THIN WALL OF ROCK JUTTING OUT INTO THE SEA.



Chicago & North Western Railroad

NATURAL ARCHED WINDOWS FORMED BY RAIN AND WIND

IN THE WALLS OF BRYCE CANYON NATIONAL PARK, CENTRAL EASTERN UTAH. THE CAPROCK IS HARDER THAN THE STRATA BELOW, PERMITTING THE FORMATION OF THESE UNIQUE STRUCTURES.

The three bridges are located about fifty-five miles west of Blanding, Utah. An automobile highway extends from Blanding to within a quarter of a mile of Owanchomo Bridge. To reach Sipapu and Kachina Bridges a long hike or horseback ride is necessary.

An intermediate stage in the formation of such a stream-formed bridge is portrayed by the Great Arch of Zion in Zion National Park, also in Utah. Here a stream in its downcutting process and lateral impingement has partially undercut a massive rock wall, forming an enormous arch. The span is seven hundred and twenty-two feet long and five hundred and eighty-five feet high. If the process were completed, the resulting bridge would be truly colossal and vastly exceeding in size even the remarkable proportions of Rainbow Bridge.

Although Utah has become noted for its natural spans cut by running water, it also has some which were not water-carved but were produced by the blasting action of strong desert winds. Wind-made arches exist in Arches National Monument, located in Grand County, in the central eastern part of the state. The monument contains two tracts, separated by a wide desert valley. One section, called the "Devil's Garden," contains balanced rocks, spires and queer sandstone formations of grotesque shapes; and the other, known as the "Windows," consists of immense sandstone walls punctured by numerous archways and windows, resembling the ruins of some great fortification.

These openings range from small windows a foot or two in diameter to great natural archways more than a hundred feet in diameter. Eight of these are of enormous size, one being two hundred feet high and nearly circular in shape. In this region strong prevailing winds pick up loose grains of sand from the desert floor, carry them for a distance, and hurl them with tremendous force against the sandstone walls, effecting a natural sandblast. During long ages the walls have been worn through at intervals, forming the many natural windows and arches. This national monument, located near Moab, Utah, was established by President Hoover on April 12, 1929.

Occasionally natural bridges and arches are formed in more unique ways. Sometimes a large boulder may become lodged after falling into the top of a crevice, thereby forming a small, but nevertheless actual, natural bridge across a gap. Waves beating upon shore cliffs may form large hollows or caves in the rocks; and portions of the roofs of such indentures may cave in, resulting in another type of natural span. Sometimes a large slice, or section, of a cliff may slump away at the base, leaving its upper

U. S. Geological Survey

PETRIFIED TREE LOG, UNDERCUT BY THE EROSION OF A STREAM PRODUCES THIS UNIQUE NATURAL BRIDGE IN PETRIFIED FOREST NATIONAL MONUMENT, ARIZONA.

portion leaning against the cliff proper and forming a natural arch.

Probably the most unique natural bridge in America is the Log Bridge in Petrified Forest National Monument, Arizona. This bridge consists of a huge petrified tree trunk spanning a gully. The trunk is one of thousands of similar specimens which lie scattered in great profusion upon the surface of the ground. The trees themselves were conifers, belonging to the group *Araucaria*, somewhat resembling modern pines, which flourished during the Triassic Period some one hundred and eighty million years ago. During their long burial in the ground the woody cells became replaced with mineral matter carried in solution by underground water. Subsequent erosion has removed much of the ground material which enclosed the petrified logs, leaving them scattered promiscuously about the landscape. A small stream, working across the region, gradually undermined one of the prostrate, petrified logs. As the gully grew beneath and beyond the site of the log, the soft ground was carried away from beneath it, leaving the petrified trunk as a natural bridge.

Like most scenic formations, natural bridges are ephemeral features in an ever-changing landscape. The same agencies which fashioned them—the waters and the winds—are relentlessly wearing away the rock grains of which they are built. Many, which existed in the past, have disappeared forever. Those which exist today will sometime disappear. But others, still in the making, will loom in their stead. Nature, the great builder and leveler of all material things, working hand in hand with time, is continually busy, designing and redesigning new structures in an ancient world.

PEYOTE AND THE INDIAN

By D'ARCY MCNICKLE

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THE search for revelation, for everlasting, fulfilling truth, has occupied men of all races, at all times. At least we must assume this, from the wealth and variety of remembered or recorded experience. And for all that it is so common a pursuit among men, it is surprising how intolerant men are of each other's vision. My prophets are but drivel-talkers to another, and another's messiah is my anathema.

The people we know as Indians were as assiduous in their search for the "truth" of things, as fertile in their imagining of creation and the world beyond life, and as sensitive to an affronting of their gods and their beliefs as any race that ever lived. Nevertheless, we frequently find people in the position of maintaining that while Indian beliefs are picturesque, interesting as specimens of benighted thought, they should not be treated very seriously. They should not be allowed to stand too much in the way of a true vision of life.

A case in point is the frequently discussed but little understood peyote cult existing in certain Indian tribes: a cult organized formally as the Native American Church in several states. In this instance, even fair-minded people who, if put to it, will concede that Indians, like all minority groups under our Constitution, are entitled to worship in their accustomed ways, draw the line at peyote worship, because—and this is odd—peyote is not native in the area north of Mexico. It is an imported religion! They do not deny that it is the product of Indian spirituality, which it is, and even recognize that it has transmuted certain Christian elements and certain Europeanizations. No matter. It was not here when the Constitution was being written; therefore it is not privileged.

As if this were not a serious enough count against peyote worship, the substance peyote has long been the object of unsavory gossip, even, at times, of quasi-scientific denunciation. It is commonly referred to as a drug, which, in a strictly technical sense, it probably is; but it is also bracketed with the term "narcotic," which many believe is usually enough to condemn it forthwith. Efforts have been made, unsuccessfully, to bar it from interstate shipment, and some states have prohibited its sale, use, possession or transportation.

What, then, is peyote? Where did it come from? And when? Why have Indians created a worship around it? Literally, it is several things: a formalized religion, as already indicated; a healing ceremony; a reweaving of the social fabric of Indian life; a sharpening of perceptive powers in the individual. When taken internally, the substance frequently induces visions and feelings of power and well-being, a kind of soft intoxication without the after effects of alcoholism.

The peyote is a cactus, *Lophophorus williamsii* botanically, sometimes confused with other plants and given various names. The ancient Mexican Indians used several narcotic growing things, one of them a poisonous mushroom, the identity of which was not at first distinguished so that even scientific literature was confused. At popular levels the confusion is even greater. In the United States, for instance, peyote

is often called the mescal bean, although it is neither bean nor mescal. Mescal is brandy made from fermented juice or pulp of the agave, or mescal, plant, not a cactus at all. The bean misnomer comes from the fact that the poisonous red seed of *Sophora secundiflora,* a true member of the bean family, has long been part of ritual paraphernalia among Indian tribes of the Southern Plains.

The most serious confusions of all, however, have been those made by careless, if well-meaning propagandists who often link peyote with marihuana, the dangerous habit-forming drug, with which it is not related either botanically or in physiological effect. Recent press articles on the peyote cult, for example, were illustrated with crime photographs of marihuana addicts taken from police files. Marihuana may be used by some Indians, as it is by other groups in the United States, but this use is not related to the peyote cult.

Most outsiders, including even those who have lived in Indian areas and believe themselves experts, have merely a superficial knowledge of the peyote cult, for while the exterior is easily seen, the inside meaning is hard to discover. Anthropologists who have investigated the cult in many tribes know that beyond the peyote-eating feature there are peculiar sociological and psychological implications.

While the peyote ceremonial reached the United States only about 1870, it was old in Mexico when the Spaniards arrived in the 1500's. There, however, it was only a small part of the whole Indian religious and curing system, not a complete religion in itself as it became in the new environment of the United States. In Mexico, peyote remains important today only among the Cora and Huichol Indians of the northern state of Chihuahua.

The ceremonial practice was brought into the United States by Apache tribes who inhabited the Rio Grande region of both countries, where the peyote cactus grows. The plant resembles a small thick carrot, its head barely protruding above the ground. This top, which contains euphoria-producing properties (as distinguished from narcotism), is cut ordinarily in October, and when dried it shrivels to the size of an overcoat button. It grows more plentifully on the Mexican side, where it is harvested and sold to United States Indians.

The Mescalero Apache of southeastern New Mexico received the ceremony at about the same time as the Texas Apaches (around 1870) and gave it to the Kiowa and Comanche tribes on the neighboring plains of Oklahoma. These two groups became the main dispersion points to other Indians of the United States. By 1890, the Wichita, Pawnee, Shawnee, Caddo, Delaware, southern Cheyenne and southern Arapaho were converts. At the turn of the century the cult existed among the Ponca, Osage, northern Cheyenne and Winnebago. By 1910 it had completed its conquest of the Great Plains and had crossed the Rocky Mountains into the Great Basin area, where Ute and Shoshone groups took it up. In the 1930's the cult crossed into Canada, where it now exists among the Cree, Blood and Canadian Chippewa, and a few years ago it appeared for the first time in northern California.

In some tribes the converts were a majority of the people, but in others the cult remained a minority practice. Its growth in each place depended greatly on the social soil it found and also on the personalities of the leaders or Indian messiahs who introduced it. The form of the cult varied too as it moved in time and space, so that it was not quite the same among the early Apache in New Mexico as it was among the recent Shoshone in Idaho or Nevada.

The appeal of peyote to the Indian mind and spirit is not too difficult to

MEMBERS OF THE PEYOTES ON THE FORT HALL INDIAN RESERVATION, IDAHO
BEHIND THEIR TEPEE AND TO THE RIGHT CAN BE SEEN CABINS AND A FEW OLD CARS.

discern. The quest for religious truth among Indians, as among other men, is a quest for power—not mundane power over other men, but the spiritual power of propitiation and supplication. A people that can not make itself heard by the supernaturals, or that has lost the power after once having had it, is a lost people. And Indians have been in exactly this situation. As they lost ground before the advancing white man, they sought frantically for the strength that would snatch them from destruction. Indian history is full of the stories of desperate messiahs who sought to lead their people into a new day. The greatest movement of this nature was the Ghost Dance religion, which started among the Paiutes in the 1870's and quickly spread to many Indian regions, wherever the fabric of the old Indian life was torn against the new white world and wherever Indian life was miserable and hopelessly disintegrated. When the United States Army suppressed the movement among the Sioux in the bitter winter of 1890, the last rebel effort of Indian life faded. A state of social frustration followed. On this fertile soil the peyote cult then grew, and some of the first peyote chiefs were former Ghost Dance leaders. The peyote movement offered peaceful conciliation and escape, rather than militant action; hence it did not arouse immediately the fear and hostility which the Ghost Dance encountered. By calling upon those very elements of Christian meekness and righteous living, which the white man had preached to the Indians, it won consideration which otherwise it would not have had. But it did not avert suspicion, and as it gained converts suspicion ripened into hostility.

It is to be expected that any substance exerting spiritual influence over the Indian mind would also find favor

as a curing agent. In Indian belief disease is commonly regarded as an evidence of displeased supernaturals. Curing the body is a matter of exercising evil and regaining the good will of the gods. The role of peyote is, indeed, of this very dual nature: the ceremony is performed as a communion of worship in which all partake, but as often as not it is a dedicated service directed at an ailing member of the group. A peyote leader could say quite earnestly—"This room [where the ceremony was held] is not only our church, it is also our hospital."

The actual ceremony varies in minor detail from tribe to tribe and from region to region, but the basic pattern is fairly constant.

Among the Cora and Huichol in Mexico the ritual is practiced at only one time of the year, but among the tribes in the United States it forms a year-round devotion. Frequently the meetings are held on Saturday night, continuing over into Sunday, following the pattern of Christian worship. Special peyote meetings are also sponsored by anyone wishing to celebrate a birthday or other special occasion, to cure illness, or to give thanks for recovery from illness. They are also held in some tribes on national holidays such as the Fourth of July.

The meeting is usually held in a house or tepee. Many an Indian who builds a new home places the door at the east, so that during the peyote meetings he may see the rising sun of Sunday morning through the entrance. In the center of the room a sickle or moon-shaped altar is built of earth or other material, its open arms, or horns, facing the eastern door. In front of it a ritual fire is kept burning. Peyote buttons are placed on the middle of the moon altar, one of these being the fetish peyote, the "father" peyote, the incarnation of spirit force. This button is treated with respect, being handed down from meeting to meeting, sometimes for many years. The peyote that is to be eaten by the worshippers is kept in a sack.

Among many tribes women were at first not admitted to peyote meetings, but this restriction gradually wore down, for they too needed curing, like the men. Today the women usually make an outside circle behind the men, who sit around the walls on the floor covered with hay or sagebrush branches. The most important person in the room is the peyote leader, or roadchief, whose name indicates that he is to lead his congregation along the road to spiritual abundance. A line often traced from tip to tip on the moon-shaped altar represents this road of life. The peyote leader stands behind the altar, facing the door. The second important official in the meeting is the fireman, who keeps a slow fire burning and also acts as doorman. The outside night is dangerous, and anyone who has to go out during the meeting must be magically protected against evil spirits, and cleansed when he returns, by the fireman. Both roadchief and fireman as well as their assistants use much ritual paraphernalia, including drums, feather fans, staves, whistles and other articles.

The meeting starts after dark, and the worshippers attend in a mood of seriousness. They try to fix their gaze on the fetish peyote on the altar and on the flickering fire, and keep away all outside thought. The roadchief prays to the Father Peyote, who is the manifest God, just as Christ is the Father incarnate. The leader eats the first four peyotes and passes the sack around until everyone has also eaten four. More can be eaten later in the course of the night, according to individual desires and tolerances for the cactus. The sick or old may be given peyote tea. The leader next sings four songs, accompanied by drumming by his assistant. These songs

INDIAN FAMILY ON THE FORT HALL INDIAN RESERVATION

IN SOUTHEASTERN IDAHO, PHOTOGRAPHED IN FRONT OF A TEPEE USED FOR CEREMONIAL PURPOSES. ALTHOUGH MOST OF THE 1,870 INDIANS ON THIS RESERVATION WEAR CLOTHES SIMILAR TO THOSE WORN BY WHITE PEOPLE, THEY ADD A BLANKET OR SHAWL OVER THEIR SHOULDERS AS A TRIBAL CUSTOM. MOST OF THESE INDIANS LIVE IN FRAME OR LOG HOUSES, BUT THEY STILL RETAIN MANY OLD TRIBAL CUSTOMS, AMONG WHICH IS OBSERVANCE OF THEIR PEYOTE RELIGIOUS CEREMONIAL IN AN OLD-FASHIONED TEPEE, SUCH AS THE ONE SHOWN HERE. THE WOMEN CARRY THEIR BABIES STRAPPED OVER THEIR SHOULDERS WITH A BLANKET OR IN A CRADLE BOARD.

THE FEAST OUTSIDE THE TEPEE AFTER A PEYOTE CEREMONIAL

THE FOOD IS PREPARED BY THE WOMEN AND OFTEN INCLUDES SUCH INDIAN DISHES AS BUFFALO MEAT. HERE INDIANS OF THE FORT HALL INDIAN RESERVATION IN IDAHO ARE BEGINNING THEIR FEAST ON LACE-INLAY TABLECLOTH.

may be very primitive, or well-known Christian hymns adapted to the occasion, or entirely new ones improvised by the singer. Each worshipper in his turn, with the exception of the women, also sings four songs. At intervals in the singing, as the peyote affects the eaters, old men pray aloud or preach in great sincerity, tears often streaming from their eyes. They may unburden themselves of their own problems or sins, or deal with the difficulties of others, or the illnesses of those present. There is a midnight break in the ceremony, when blasts from a whistle are blown, four of them outside the house or tepee, to let all living things in all directions know that the people are gathered there and need their help and power. Water is passed around and drunk, and the singing, praying and preaching are resumed, filling the rest of the night. At dawn the whistle blows again, a woman brings fresh water, and a ritual breakfast follows. Sweet foods are included in this meal, although their symbolical meaning is forgotten. After breakfast the meeting is officially over, and people for the first time walk around and talk to one another, telling what experiences or visions they had under the influence of peyote, or they lie around and sleep. At noon a second meal is served, and after this everyone goes home.

One appeal of peyote to the individual would naturally be the sensory stimulation produced, the feeling of ease, well-being and detached superiority. Another appeal is its prestige value, for the peyote user is a person more important than the nonuser, in the eyes of his companions. In olden times, and especially in the Plains area, centuries before the peyote cult, visions used to be sought often through drastic means and trials of endurance, and the person attaining a vision became an important individual. Some association with the former vision-quest doubtless exists in peyote, explaining further the appeal it has for the Indian mind.

Research into the physical properties of peyote, or of its physiological effects on the human organism, has not been ex-

haustive. It is by very reason of this incomplete knowledge that the attack on peyote has been so successful at times. Charges are made against it that are difficult to disprove, the facts being inconclusive. Probably, also, it is not unfair to say that those who attack the cult make maximum use of what little evidence is available; while the friends who would protect the cult, and they have never been numerous, have found the scarcity of evidence a handicap. We summarize the material briefly.

A number of alkaloids, including mescaline, anhalonine, anhalonidine, lophophorine and others, have been isolated from peyote, but none has ever attained commercial or pharmaceutical importance. Physiological and psychological experiments have been made with different ones of these compounds and also with the crude plant material as a whole, but the tests have not been made under strictly standardized conditions, either as to the strength of the drugs or as to the subjects on whom they were tried. Nevertheless, certain physiological effects are sufficiently constant to be worthy of note, and these may be considered in relation to the organs of the body upon which they are most marked.

The general effects of peyote are a feeling of overfullness in the epigastric regions, a sense of heaviness in the head, and rapid respiration. With larger doses, diarrhea and profound intoxication with a feeling of suffocation may be produced. The circulatory system responds at first with an increase in blood pressure and strength and volume of pulse, followed by a weakened rapid pulse, slowing heart and increased arterial tension. These combined stages may take from eight to twenty-four hours or even longer.

The physiological effect on the central nervous system is first one of exhilaration, excitement, and a sense of well-being. S. Weir Mitchell, in the *British Medical Journal* in 1896, described a "delicious languid sense of ease and elated sense of superiority." This is followed by a second stage of relaxation, depression and feeling of exhaustion, although with sleeplessness, unaccompanied, however, by any uneasy or restless feelings. If the dosage has been sufficient this stage may be followed by one of prolonged sleep.

In the first stage there is evidence of agitation, expressed in talkativeness and a desire to walk. The talk may become incoherent and confused. In the second stage the pupils are widely dilated; there come an inclination to lie down and an incoordination of muscular action. The walk becomes irregular and staggering. Muscular tremor is evident, especially in the outstretched fingers.

The nerves of special senses are most affected. This is accentuated in the sense of sight. Vision may be disturbed to an unbelievable extent. Those who have approached intoxication by peyote nearly always have illusions of brilliant hues following one another in rapid and peculiar succession, whether the eyes are open or closed. The other special senses do not appear to be so much affected, although there is usually some disturbance of them all. Havelock Ellis, another who in the early years of interest in peyote took an infusion of the drug, went through a first stage of exhilaration, which however passed quickly. This was followed by heightened muscular irritability, faintness, difficulty in concentrating attention, singing in the ears, a vague sense of perfume in the air and color visions. All objects presented a heightened color, and vague shadows floated before the eyes, giving the room the appearance of a picture rather than of actual reality. The effects vary greatly with the individual, and visions tend to project the personality of the user.

Recent investigators also report two

PART OF A GROUP AT A PEYOTE CEREMONY IN THEIR CEREMONIAL TENT
PRESENT-DAY POLICIES MAKE NO ATTEMPT TO THWART TRIBAL CUSTOMS AND RELIGIOUS CEREMONIALS AS IN THE PAST, BUT GUARANTEE INDIANS THE RIGHT TO WORSHIP AS THEY PLEASE.

stages, the first sometimes described as one of mental contentment and exaggerated acuteness of certain senses, and the second as one of nervous calm and hypercerebrality, when thinking appears to be sharper and clearer. During these stages consciousness is never lost although there may be extreme physical relaxation.

From all that is thus far known, peyote causes little if any moral or social degradation and, despite the claims of its antagonists, does not stimulate to acts of violence and is not aphrodisiac. Some observers believe it dulls rather than excites sex feelings. Indians claim that peyote cures drunkenness, and while there is some evidence in support of this, the truth probably is that the peyote cult creates a social situation in which drinking is undesirable. Some peyote groups actually prohibit the use of alcohol.

One interesting aspect of the peyote cult today is that it is actually an Indian form of Christianity, this factor varying among the tribes. Christian hymns are often sung in meetings, and the Bible is sometimes seen on the altar with the fetish peyote. Most important of all, the moral values of Christianity pervade the peyote cult, even though the form of the rite is still Indian. Worship, humility and good will to men are greatly stressed, while Indian religious forms continue to exist. The Indian actually merges the two religions. He believes that the white man's God and his own are the same, but that each approaches him in his own way or by his own road. The white man has for this purpose Jesus, the Cross and the Bible, while the Indian has peyote. In this way the Indian does not destroy or belittle the white man's faith or his own. He has solved one important problem of the impact of the two civilizations.

Mention has been made of the function of peyote as a curing ceremony. It is

MEMBERS OF A PEYOTE CEREMONIAL GROUP SEATED AROUND A FIRE
A HALF-MOON ALTAR MODELED OUT OF EARTH IS VISIBLE IN THE FOREGROUND.

also used as a specific remedy by many Indians for every conceivable illness and is even reported to have been used, in liquid effusion, as an antiseptic wash for open wounds. One writer reports the statement of a Kickapoo Indian that peyote is used "as white man uses aspirin." In spite of this constant, almost daily use that some Indians make of it, it is not habit-forming.

In most cases, doubtless, there is an important psychotherapeutic effect. The patient believes in the power of the god-plant as he feels it working on his body and his mind, and he knows also that the roomful of worshipers around him have combined the force of their minds on his recovery. Anxiety is dissolved and security increased, so that the body is unhampered to restore itself.

Physical illness of predominantly psychological origin often yields before peyote, as before other native curing ceremonies. Personal conflicts are more easily seen through, or psychoses exteriorized, under the cerebral stimulation of peyote. Some peyote users drink an infusion of the substance between meetings, when facing a difficult problem, in order to "sharpen one's mind." Self-searching is undoubtedly helped in the meetings by the sincere mood of the worshippers, the force of all the others bent on the same purpose, the mental concentration of the individual, and the perhaps hypnotic effect in these circumstances of the flickering fire, the rhythm of the drum and the moral suasion of the songs. Sometimes the suffering person himself, and sometimes another, suddenly sees through a situation which has been causing conflict, and the right thing to do is suddenly clear. The solution is considered to have come on the highest authority, for peyote is believed to be God's guidance, and the worshipers have faith in it. The peculiar physiological effect of the drug in enabling a person to see himself as if he were another person may also help in the auto-analysis. The confessions in public to the peyote god, and the repentance of individuals before the entire group, constitute a salutary practice, simplifying the mental states of the participants.

Those who would belittle the peyote

cult as not constituting a true religion overlook the fact that while the physiological effects of the drug are the basis of the faith, these effects are religiously interpreted. In the Indian mind peyote is the incarnation of the God spirit. Peyotism, moreover, is not too strange a form of religion. Plant worship as such has existed in other times and places. The incarnation of spirit force in something material like peyote also has its counterpart in the Christian religion, in the sacramental wine and consecrated wafer. As far as a drug-taking religion is concerned, one anthropologist points out that the Zend Avesta, the sacred scriptures of the ancient Persians, which contain some of the loftiest thoughts of mankind, came out of that kind of a religion.

Like the Ghost Dance, the peyote cult has given some internal strength to Indian groups that had become almost atomistic, scattered population pieces, without organization or coherence and without a point where governmental programs for economic betterment could take hold. One anthropologist reports that peyote has integrated one Indian reservation group in just this way.

This strengthening has happened not only within groups but also between different tribes. Where formerly intertribal rivalry and even war prevailed, the Ghost Dance and now the peyote cult have brought about intertribal relations instead. There is an organized intertribal peyote religion, incorporated legally in Oklahoma and South Dakota as the Native American Church. Common symbols on jewelry and clothing worn by peyote people are an expression of their oneness, and there is no distinction by tribe.

For those who fear the peyote cult, this summary can be made. Peyote use has been confused with some existing evils, but it does not represent such an evil in itself, in the opinion of the best experts. Most important of all is the social significance of the cult, which anthropologists can explain but which the casual observer must miss. Further, there is the probability that the peyote cult forms only a passing phase in modern Indian life. It has shown a tendency to fade out in the early part of its trail, or lose its great significance, perhaps because it too, like the Ghost Dance, fails in the end to fulfill its promise. But the peyote cult has offered the Indian an assuring foothold for a moment, when he needed it, in the changing world.

SWEDEN LOOKS TO ITS AGRICULTURE

By EWERT ABERG

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SWEDEN, one of a few small nations in Europe that is still neutral, has occasion to worry about food production as well as defense. When the people of Sweden, in 1938, realized that war was developing in Europe they knew that isolation, far worse than was their lot in the first world war, was coming. However, the nation was much better prepared for farm production during a period of isolation than during the last world war. This more favorable condition may be attributed to the intensive work in soil, farm crops and animal husbandry and to the rapid development in plant breeding. Equally important during a crisis like the present are youth movements among the farmers and cooperative farm associations, which are widely spread in Sweden. These organizations have educated the farmers so they are eager for advice and suggestions as to how they can cooperate with one another and with government agencies—both tremendously important at the present time.[1]

Being located far to the north, Sweden does not have the climate or the lands particularly favorable to farming. Only 9 per cent. of the total land area, or 9,312,000 acres, are cultivated. In spite

[1] Åberg, Ewert, "Solving Farm Problems in Blockaded Sweden," *The American Swedish Monthly*, 1941. Vol. 35, No. 12, p. 11.

"Sweden adjusts its agriculture to war conditions," *Foreign Agriculture*, U. S. Dept. of Agriculture, Washington, D. C., 1942. Vol. 6, No. 1, p. 3.

"How Sweden Feeds Herself," *American Scandinavian Review*, 1942, p. 60.

FIG. 1. A TYPICAL WINTER WHEAT FIELD IN SOUTH SWEDEN*

* Figs. 1, 2, 4, 5, 6, courtesy the Swedish Travel Information Bureau, Inc., New York.

FIG. 2. MAIN BUILDING OF THE PLANT BREEDING STATION AT SVALÖF

of this the goal of Swedish agriculture is to bring the total farm production high enough to make Sweden independent of importation of farm products. In this work the agricultural experiment stations, during the last twenty-five to thirty years, have labored arduously to obtain ways and means to reach this goal.

The soil of Sweden needs much careful attention. Drainage of the soil was introduced early and today most farms are drained satisfactorily. The Swedish soils need complete fertilizers, *i.e.*, nitrogen, phosphorus, potash and lime, for the production of good crops. For a long time the experiment stations and the local agricultural associations have conducted field experiments to determine fertilizer needs. Since most of the fertilizers normally are imported to the country, it is very important that they be used as efficiently as possible and applied only where they are absolutely needed. This can be done if each farmer has a map of his fields showing the state of fertility. It is, however, too expensive to make maps for each farm on the basis of fertilizer experiments. Therefore the present system is to use chemical analysis of the soil or of the plants grown. Maps of the individual farms are then based on the chemical analysis and they indicate where fertilizers should be used and the amounts that should be applied. This "soil mapping method" has been introduced recently. Plans for drainage, the application of fertilizers and cultivation methods with modern machinery are important preparations for growing crops according to new methods of farming.

The old type of farming was mainly based on the production of rye, barley, oats and wheat, and of grasses and clovers for hay or pastures. As the soils were improved new plants came into the picture. Potatoes were introduced late as compared with the cereals and grasses; sugar beets were still later. Oil- and protein-plants were the latest introductions and were never considered important before the war brought isolation. When the importation of proteins and fats was cut off the Swedes began to understand that the growing of oil- and protein-plants was vital to the nation, and was of the same importance as the growing of wheat, potatoes and sugar beets. Of the protein plants used for direct human consumption, only yellow

peas and to a certain extent kidney beans were grown extensively enough before the present war to be considered important. Oil- and protein-plants for industry or for fodder, such as soybeans, seedflax, sweet lupine and poppies, were hardly heard of before the present isolation.

With new plants and with better farming practices, increased yields were natural. The total yield of wheat in 1938 was more than three times higher than the average yield in 1911–1915, while the total yield of rye in 1938 was three fourths of the average yield in 1911–1915. A shift from rye to wheat has taken place. The total bread cereal production in 1938 was 1,226,000 tons, as compared to 853,000 tons in 1911–1915 and to 570,000 tons in 1871–1875. The yield in 1938 was high enough to make Sweden self-sufficient with bread cereals. The high bread cereal production in recent years is dependent not only on an increase in lands used for wheat but also, and very much so, on the increase in yields per acre. Winter wheat yielded thirty-eight bushels per acre in 1938, compared with nineteen bushels in 1871–1875; for spring wheat the figures were twenty-seven and eighteen bushels, respectively, and for rye, twenty-seven and eighteen bushels. With sugar beets and potatoes similar results have been obtained. Since 1913 the sugar beet production has been doubled and was estimated to be 2,035,000 tons in 1941 and 1,750,000 tons in 1942. The yield of potatoes was reported to be 2,072,000 tons in 1941 and 1,800,000 tons in 1942. The per acre yield of potatoes had increased from 106 bushels in 1871–1875 to 180 in 1938. Sufficient amounts of both potatoes and sugar beets are produced at the present time to supply the nation's needs.

However, this is not the case with feed grains, for barley and oats have in many places been replaced with bread cereal, and the increases in yields per acre, although high, are not enough to make the total yield of feed grain sufficient for the nation's need. In 1871–1875 the yield of barley was nineteen bushels per acre, in 1938, thirty-two bushels; for oats

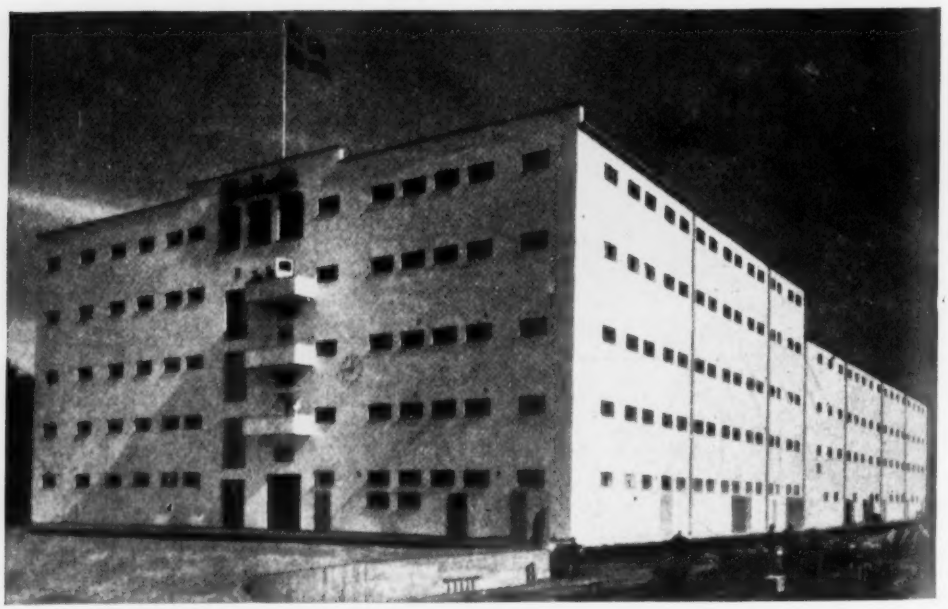

FIG. 3. SEEDHOUSE, WEIBULLSHOLM PLANT BREEDING STATION

the respective figures were seventeen and twenty-seven bushels. Importation of corn and small grains for fodder is necessary and this is true also for protein- and oil-cake for cattle feeding. High increases in the total production of grasses and clovers for hay or grazing purposes have been obtained. It is estimated that the annual average feed units from forage crops during the five-year period, 1931–1935, was 3,920 million, which is 44 per cent. of the total feed units produced annually in Sweden during that period. Further increases are both possible and necessary.

The increases in yields of different crops during the last century can be credited to two lines of work: plant breeding and better cultivation and handling of crops. Plant breeding started with small grains and root crops about fifty years ago. The main plant breeding work is now carried out at Svalöf and at Weibullsholm. Important varieties of grain, such as *Victory* oats, *Standard* winter wheat and *Golden* barley, have been bred at Svalöf and Weibullsholm. These varieties have been tremendously important in increasing the per acre yield not only in Sweden but also in large areas over the rest of the world. In the summer of 1941 fields of Victory oats in the United States proved that it really takes a long time to breed varieties that surpass them in yields. Victory oats were released more than thirty years ago. Standard wheat and Golden barley released twenty or thirty years ago, are still used in some areas in Sweden. Other important varieties have been bred; examples of some of the more recent ones are the following: Winter wheat—*Skandia II*, *Äring III*, *Gluten*, *Ankar II*, *Ergo*, *Sun IV*, *Gyllen II* and *Jarl;* oats—*Bambu*, *Sun* and *Eagle;* barley—*Freja*, *Balder*, *Edda*, *Puke II* and *Dore;* and spring wheat—*Atle* and *Diamond II*. The type of wheat that is used and to which the mentioned varieties belong is shown in Fig. 1.

At the present time there is in Sweden a very intensive breeding program with forage grasses and clovers. Most of the strains on the market today are results of selection, and the advantage of local strains is very important, particularly in the case of red clover, Sweden's number one legume for meadows (Fig. 4). Importation of red clover seed from continental Europe has been abandoned and the advice to the farmers is now: "Buy your seed from your local district or produce it on your own farm." This is true also for seeds of plants other than the red clover. Sugar beet seed is now produced in Sweden instead of being bought from Germany. The Swedish Sugar Company has its own plant breeding station at Hilleshög, Landskrona. There is perhaps no other country in the world which can show as definite results of the importance of right varieties or strains in the right place. The use of correct varieties is closely dependent on a reliable seed trade. It is then easy to understand why the seed certification has developed rapidly. With as many new varieties of cultivated plants as there are in Sweden, there is a real need for a certification system that guarantees that the farmers get the correct varieties. If they do not, it means extensive losses for the farmers as well as for the nation.

Research workers have studied the methods for growing the plants produced by the plant breeders. In addition to being dependent on the improvement of the soil, as discussed earlier, the increases in yields per acre are dependent on better seeding, harvesting and drying methods. Regular crop rotations are generally followed. They include fallow, small grains, root crops, legumes and hay meadows. The use of these regular rotations prevent depletion of the soil and increase the per acre yield of the plants. The important gains of fodder that have been secured from pastures and hay meadows depend on a number of factors. The meadows are most often

seeded with early small grain as a nurse crop and the clovers and grasses are drilled, which is also the case with grasses and clovers for pasture. No nurse crop is used, however, for seeding the pastures. The old method of broadcasting the seed in fall-sown nurse crops has been almost entirely abandoned. Rotational grazing of the pastures is absolutely necessary for establishing a good stand. Blue grasses, rye grasses, timothy, fescues, redtop and white clover are the most common pasture species.

The pastures along with hay production have made it possible to increase the livestock and bring dairy production up to its present high standard. The pastures are especially important for the dairy production in middle Sweden. The cattle used there are the Swedish Red and White. The cows average 1,150 pounds in weight and produce about 8,800 pounds of milk per year with an average butter fat content of four per cent. In the southern parts of Sweden the heavier Swedish Friesians are popular (Fig. 5). These cows weigh about 1,325 pounds and they give about 11,000 pounds of milk with 3.5 per cent. butter fat. Before the war butter was one of Sweden's most important farm products for exportation. In 1939, 3,200,000 tons of milk were delivered to the creameries, which meant an increase of almost three times that of the 1913–1915 average when 1,214,000 tons were delivered. In 1939 Sweden produced 184 million pounds of butter and 96 million pounds of cheese.

The increase of livestock resulted not only in a higher production of dairy products but also in a higher production of meat. Need of cooperative associations for solving marketing problems for dairy products and meat arose and the "Swedish Dairies Association" and the "Swedish Federation of Meat Marketing Societies" were organized in 1932 and in 1933, respectively. They have been followed by a number of other organizations and at the present time every farmer is a member of some cooperative organization. The cooperative associations,

FIG. 4. A RED CLOVER FIELD IN SOUTH SWEDEN
THE MOST IMPORTANT LEGUME IN THE SWEDISH MEADOWS IS RED CLOVER.

FIG. 5. CATTLE GRAZING IN SOUTH SWEDEN

through meetings, shows, journals and the radio, have helped to educate the farmers in fields where the schools have left off. When the war began in Europe and the isolation of Sweden became a fact, Swedish farmers were organized in cooperative associations and ready to do what they could to produce enough food for the nation. They were also ready and willing to adapt new methods for farming, as well as to try farming under extreme conditions.

With a development of the agriculture in a democratic nation like Sweden, it was only natural that the Government should pick a group of men representing research work and farming to form a committee for solving important food production problems. This was done in the fall of 1938. The main thing the men of the committee did before the war started in 1939, and before the complete blockade of Sweden came in the spring of 1940, was to arrange for the storage of certain foods, livestock feeds, fertilizers, gasoline and oil. They planned and organized an increased production of a number of foods inside Sweden. If the weather conditions had been normal there would have been only one real big farming problem during the isolation: *the production of fat and protein.* Extremely low yields of 1940 and 1941, resulting from cold winters and dry summers, changed the conditions so much that there is now, in addition to greater difficulties in producing fats and proteins, also difficulties in producing enough bread cereals. Fiber and rubber are also on the list of badly needed plant products. Consequently the farmers are now faced with problems of increasing the production of oil and protein plants, sugar and starch plants, fiber plants and rubber plants.

It may seem almost impossible to suddenly increase this production in a nation where the farmers are already using a regular crop rotation system and where every acre of soil that can economically be used is under cultivation. There is no other possibility than to cut down on some of the less important and low yielding crops and to use the lands so obtained for crops which are vital for the nation's food situation. And that is also what has happened. The acreage of sugar beets, wheat, and rye is increased by abandoning the fallow and by avoiding the use of meadows for more than two years in the crop rotation. In a number of places the meadows are normally used for four or five years. The yield after two years of meadow is, how-

ever, too low to compete in feed units with the yield from a wheat crop. Wheat has replaced oats to a certain extent because of its higher food value. To further promote the increased growing of bread cereals, a part of the price of the wheat and rye is paid in the form of a bonus per acre seeded to these crops.

Protein and fat production are increased in two ways. It is easiest done by taking still better care of the grasses and legumes in the pastures and meadows. There the use of right varieties or strains is coming into the picture. Also the curing of hay is very important and it is estimated that about half of the feeding value in the concentrate feeds, normally imported to Sweden, could be obtained by using drying methods that quickly reduce the moisture content of the plants so that storage can be safely made. Still more can be obtained by artificial drying in electric driers. This method, which came to Sweden from England five or six years ago, is still in the experimental stage. The increase in feeding value of the dry product compared with the feeding value of field-dried hay is, however, so great that, with the cheap electricity in Sweden, it will be possible to develop the method to economic practicability. The moisture content is reduced to 10 per cent. by drying the forage crops at 250° Centigrade for ten minutes. The dry product is considered at least twice as valuable as that gotten from usual field curing methods. Since the isolation the use of silage became more common. It appeared to be the best method of preserving certain products that normally are fed green or are not used for fodder. Silage is, for example, made from potato-tops, sugar-beet-tops and grasses from lawns in the cases where the lawn grasses are not allowed to grow high enough to be cured for hay. The A.I.V. method, named after Professor Arthuri I. Virtanen in Helsinki, is now being used in the preservation of forages. In the process the green material is preserved by adding sufficient dilute mineral acids (sulphuric

FIG. 6. HORSEPOWER IS AGAIN IMPORTANT IN SWEDISH AGRICULTURE

and hydrochlorie) at the time of packing the material into the silo.

The protein products derived from grasses and clovers are not enough, as their main value is feed for the livestock. Only indirectly do they influence the fat and protein supply for direct human consumption. The production of oil and protein plants yielding fat and proteins for direct human consumption have been tried with diverging results. Yellow peas and kidney beans are well adapted for Swedish conditions. Boiled yellow peas have always been a standard dish for Swedish homes and are now more important than ever. They are badly needed for the Swedish army at the present time. A number of good varieties are available and the area given over to peas has been increased since the beginning of the war. Kidney beans are as well adapted to Sweden as yellow peas, but before the isolation were grown mostly in gardens. Now they are being produced successfully in field quantities. Soybeans were introduced in order to get the oil for certain industries, but they are not very well adapted to the cold climate and the short growing season. Intensive breeding of soybeans is therefore a necessity, and that is true also for other new oil plants such as seed flax, rape, sweet lupine and poppies. But even if these new oil plants are not well adapted for Swedish conditions, the area given over to them in 1942 was about 45,000 acres. The area for increased production of oil and protein plants was obtained mainly by cutting down the area in oats.

Flax and hemp were grown during earlier periods as fiber plants but were rare when the present isolation came. However, the area used for them has been rapidly increased and during 1942 about 5,000 acres of flax and 2,500 acres of hemp were seeded. This means that about one fourth of the need of flax and almost the total need of hemp was covered by domestic production in 1942.

FIG. 7. AGRICULTURAL COLLEGE
ONE OF THE BUILDINGS AT THE COLLEGE LOCATED AT UPPSALA, THE CENTER FOR AGRICULTURAL EDUCATION IN SWEDEN.

The only rubber plant that seems to have any future in Sweden is the Siberian dandelion, or kok-saghyz. Experiments with this plant were started in the spring of 1942 and definite results can not be given at this time. However, if the normal need of rubber in Sweden should be obtained only from kok-saghyz, an area of 240,000 acres would be necessary.

The introduction of new plants and of new farming methods necessarily brings up the need for more labor. As the greater number of the farms in Sweden are small, there is much need for hand labor. Necessary calls of young men to the army were expected to upset the farm production program. The difficulties have been overcome by organization of cooperative "labor units." The idea is to group a number of small farms into one unit and select one of the men on these farms as the leader of the unit. If necessary all available men, horses and machinery can be placed under his command. This makes it possible to get more work done than when every farmer does his own work on his own farm. The women have also declared their willingness to help the farmers by organizing committees for training the women in farm work and for distributing available trained women laborers to farmers.

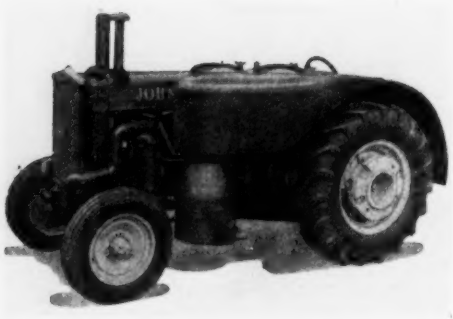

FIG. 8. TRACTOR
BUILT FOR DRIVING WITH CHARCOAL OR WOOD.

The shortage of gasoline, kerosene and oil for the operation of tractor driven machines appeared to have limited the use of tractors when isolation of Sweden first occurred. But now the tractors are driven by gas generated from charcoal or wood. The gas is produced in stove-like generators, placed on the side of the tractors (Fig. 8). Charcoal or wood is burned in these generators and the important products in the obtained "gengas" is carbonmonoxide (CO) and hydrogen (H_2). "Gengas" from charcoal contains about thirty per cent. carbonmonoxide and twelve per cent. hydrogen, and "gengas" from wood contains about twenty-two per cent. and eighteen per cent., respectively. Even if the efficiency of the motor is cut to thirty or forty per cent., as compared with the efficiency with the use of gasoline or kerosene, the results are satisfactory to the farmers. At the beginning of 1942 it was estimated that 5,000 tractors had been rebuilt for use of "gengas," which is about twenty-five per cent. of all Swedish tractors.

Without a rationing system there would not by this time have been food enough for all the Swedish people. The rationing was introduced during an early stage in the isolation period and is extended now so that the only farm products not yet rationed are milk, vegetables and potatoes. Besides rationing, other steps have been taken to secure enough food of which the following are examples. Since November 1941 the milk for consumption was standardized to contain 3 per cent. butterfat in order to obtain enough fat for a normal butter production. In April 1942 the milk production had decreased twenty-six per cent. of that in 1939, while the butter production had decreased about twenty per cent. About 800,000 tons of bread cereal were needed for flour production during 1941–1942 and the yield of wheat and rye was 620,000 tons in 1941, which is 55–60 per cent. of normal yield. To these 620,000 tons there were added 60,000 tons stored from the wheat crops of 1938 and 1939. Furthermore, 40,000 tons of barley and 15,000 tons of potato starch were mixed with the wheat. There was then a shortage of 65,000 tons, which was compensated for by using the whole wheat flour. The barley for mixing with the bread cereal was obtained by cutting down by 80 per cent. the amount of barley for brewing and distilling. In 1942 the yield of bread cereal is estimated to be about 965,000 tons, which is about ten per cent. below the normal yield. But this yield makes the situation brighter for 1942–1943 as far as bread and flour are concerned. It is, however, likely that a certain amount of the 1942 crop will be stored as a reserve in case the 1943 yield is low.

It is quite obvious that price increases of the farm products are necessary if the farmers are to continue production under the conditions as discussed here. But it is also necessary to keep the consumer-prices as nearly normal as possible. The Swedish Government takes the responsibility for the difference between the farmers' and the consumers' prices by paying a bonus to the manufacturers as, for example, to the creameries and millers. As almost all creameries are organized in one cooperative association the support to them is paid through this

association. Once again the advantage of the cooperative associations during the present crisis is demonstrated. The price control on farm products in Sweden seems in most cases to follow the principle of getting by taxes the money that is needed for standardizing the prices so that they satisfy both the producer and the consumer. The average price increases are not very high. In August 1942 the total living cost in Sweden was forty-six per cent. higher than in August 1939.

It is hard to say what will be the best lesson obtained from the isolation. But it is quite clear that the production of fats, and proteins and fiber will be increased in an attempt to make Sweden self-sufficient for these products. Still more important is the result that the whole crop production program will be based on the idea of producing necessary foods and other essential crops. This means an adjustment of the farming conditions from year to year. The agriculture will have to be a dynamic one, which is only possible with intelligent, well-educated farmers and laborers. They are needed in the future farming and they will no doubt be found if the present school system and youth movement programs continue to work. With the cooperative associations' help, every man in farming will be better able to understand his own vital importance and his responsibility in the community. As he does so he will be able to do his part of the work much better. This will mean a step towards a still better agriculture in Sweden.

THE ROLE OF PETROLEUM IN THE MIDDLE EAST

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THE geographical triangle, lying within the boundaries that join the Mediterranean, Black Sea and Indian Ocean, vaguely known as the Middle East, is the crossroads of the Old World. This region contains the gateway to three continents, the entrance to southern Europe through the Vardar Valley of the Balkans, the overland route to India by way of Baluchistan, the backdoor to Russia through Iran, and the principal route to central Africa by way of the Nile River. However, the Middle East is not only important from a purely strategic point of view but also has many natural resources that are vital to a war economy. In area the Middle East is almost as large as the United States, but has little more than half the population. Today about ninety per cent. of the people are dependent for their existence on agricultural pursuits. Nevertheless, only eighty thousand of the total of two million five hundred thousand square miles are devoted to crops, about twice that to grazing, and some seventy thousand square miles to forests. The remainder, about eighty-eight per cent., is desert, fen or barren mountains.

Although agricultural resources are greatly limited, this area contains patches of exceedingly productive land in the irrigated sections of Palestine and Syria, on the alluvial plains of the Tigris, Euphrates and Nile Rivers, and in a number of the desert oases of Arabia. Of the various cereal crops, wheat, barley, rice and millet are most widely cultivated. Other agricultural commodities are cotton, dates, tobacco, olive oil, fruits, nuts and wool. Of these, dates, cotton, tobacco and wool products are important in international trade.

Although the Middle East is moderately rich in mineral resources, development has lagged, mainly because of poor transportation facilities, long distance from market, and the lack of coal for smelting purposes. There are considerable deposits of chromium, iron, manganese, copper, zinc, antimony, lead, silver, gold and mercury. However, from a military viewpoint, the richest prize of the Middle East is the vast petroleum resources of Iran, Iraq, Saudi Arabia, Bahrein Island and Egypt. The exploitation and refining of petroleum is the most important mineral industry of the region. Because of the international significance of petroleum, it exerts an important influence on the economy of the Middle East. Today this industry has greater importance than at any time in the past, for the United Nations are dependent upon the oil resources of this region to supply with fighting fuel many of the battle areas of the world. The loss of these oil fields would not only give a source of oil to the enemy but also would relegate the Allied Nations to complete dependence on petroleum from the Americas.

IRAN

Mineral oil from seepages in Iran was collected as early as 500 B.C. and at the time of Herodotus its uses ranged from the making of mummies to the waterproofing of cisterns, silos and ships' hulls; binding of building blocks in Babylon, and application in the arts of the painter and apothecary. However,

it was not until 1901 that the first concession for the exploitation of oil was granted in Iran. It was made to an English adventurer, D'Arcy, for a period of sixty years and included all of Iran except the five northern provinces that came under the influence of Russia. At this date it was exceedingly difficult to transport drilling equipment in the country, for there were no railroads, and north of Baghdad no waterways were navigable. The work of drilling was equally difficult, but in 1903 oil was discovered near Chiah Surk close to the Perso-Turkish boundary. Because of the lack of transportation and the limited amount of oil, development lagged. In 1908 large quantities of oil were discovered near Masjid-i-Sulaiman in southern Iran, and in 1909 the Anglo-Iranian Oil Company was organized. It required three years to develop commercial production and to lay a pipe line to the Persian Gulf. The first crude oil was exported in May, 1912, and a refinery was constructed at Abadan early in 1913. The British Admiralty owned most of the shares of the Anglo-Iranian Oil Company, and during World War I there was a grim struggle for control of the field and the pipe line to the coast.

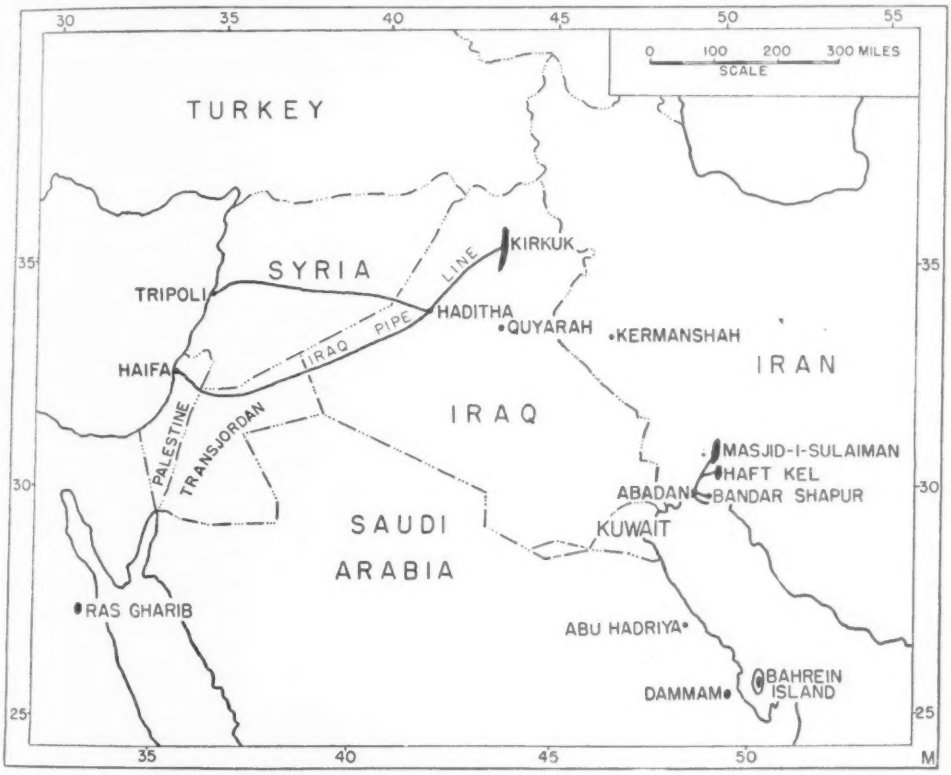


FIG. 1. REGIONAL LOCATION OF THE OIL FIELDS WITH THE MAJOR PIPE LINES OF THE MIDDLE EAST.

Exploitation of the oil resources proceeded slowly on a prorated production schedule during the 1920's. In 1932, as a result of the growth of nationalistic policies in Iran and the aim to eliminate foreign influence, the Shah of Persia cancelled all foreign oil concessions. The dispute was placed before the League of Nations. The concessions were adjusted

to be legally binding for another sixty years, but the Anglo-Iranian Oil Company had to pay a fixed price for each acre of concession and a twenty per cent. royalty fee on each barrel of oil produced instead of the previous sixteen per cent. net profit. The treaty also provided for a progressive Iranization of the oil workers. Finally, before the end of 1938 the Company had to choose from the original concession one hundred thousand square miles to be the actual field of development while the remainder reverted to the Iranian government.

The oil districts in Iran are considered to be among the richest in the world. The southern fields of Masjid-i-Sulaiman and Haft Kel are the largest producing fields in the country and are both connected by pipe line to Abadan. Other fields in southern Iran at Lali, Agha Jari and Gatch Saran have been developed with excellent potential output. The oil formations are twenty-five hundred to six thousand feet deep, and the crude is around 37° gravity—A.P.I. The northern fields of Naft-i-Shad and White Oil Springs are considerably smaller than those in the south. In 1940 there were seventy-five wells in the country with a restricted production of 131,000 barrels a day. Iran in 1940 was the largest producer of oil in the Middle East and the fifth largest producer in the world, with a production of 78,592,000 barrels.

At Abadan one of the world's largest refineries is located. This modern refinery has capacity to process 280,000 barrels of petroleum a day. The production of high octane aviation gasoline began in 1931, and the "cracking" facilities are now 125,000 barrels a day. The storage facilities amount to about six million barrels in the form of seventy thousand-barrel tanks located on two large tank farms. Two oil-loading jetties for deep-sea tankers have been built along the Abadan-Bavarda shore, in addition to a quay 1,350 feet long. There are also several jetties for loading barges with oil for shipment on the Euphrates, Tigris and Karun River systems.

A second refinery in Iran, located at Bandar Shapur on the Persian Gulf, has a daily capacity of fifty thousand barrels. It also gets its oil from Masjid-i-Sulaiman and Haft Kel. The refinery has facilities for producing thirty thousand barrels daily of high octane gasoline. The petroleum in northern Iran is refined at Kermanshah. The refinery capacity is small, around three thousand barrels a day, and the products are consumed locally.

Iraq

The securing of concessions for the exploitation of the Iraquan oil fields has an interesting history. The first grant was given prior to World War I to the Anatolian Railway Company (a German company associated with the Berlin to Baghdad railroad enterprise). The concession was not clearly confirmed by the Turkish government, and another company under British control also obtained a concession. During the war, control of the Anatolian Railway Company passed into British hands, and along with it went whatever rights may have existed in the company's oil concessions.

After World War I, since the Ottoman Empire was no longer in existence, a struggle ensued over the validity of the British concession and the national ownership of the oil districts. The League of Nations finally assigned the oil fields to Iraq, and the Iraq Petroleum Company was organized (familiarly known as the I.P.C.). Ownership of the I.P.C. is divided between the Anglo-Iranian Oil Company, Anglo-Saxon Petroleum (owned by the Royal Dutch Shell interests), Cie. Française de Petroles, and the Near East Development Company (owned jointly by Standard Oil of New Jersey and Socony Vacuum).

Each of these participants owns 23.75 per cent. A private individual, an original concessionaire, owns the remaining five per cent.

The development of the oil districts in Iraq was retarded greatly because of the lack of transportation facilities for the crude oil. The completion of the fifty million dollar Iraq Pipe Line in 1935 was the first impetus to extensive exploitation. Production increased from seven million barrels in 1934 to twenty-seven million barrels in 1935. The pipe line starts at Kirkuk and runs to Haditha where it bifurcates, one branch extending to Haifa in Palestine and the other to Tripoli in Syria. It is 1,150 miles long and has an annual capacity of about twenty-eight million barrels. The construction of this pipe line was one of the greatest engineering feats in the Middle East. Extreme heat and cold, rugged terrain, swiftly flowing mountain streams, and laying pipe through lava beds all contributed to the hardships of construction.

The major producing field in Iraq is at Kirkuk. It is about sixty-five miles long and has an average width of about two miles. Sixty wells have been drilled in the productive area. Many of them have a production of ten thousand barrels a day but are restricted in output to conform to market conditions. The Kirkuk crude is around 36° gravity A.P.I. (a fairly good grade) and is produced from formations 2,100 to 2,200 feet deep. The field has been developed as a unit operation employing modern scientific methods.

Seventy miles south of Kirkuk, on the banks of the Tigris River, the Quyarah field is located. It has a potentially great production, but the crude oil is of so poor quality that output is greatly restricted. The oil is used only for local fuel and road oil requirements. There is also a small producing center near Naft Khaneh on the Iranian border.

There are no large complete refineries in Iraq. However, before the crude is pumped through the Iraq Pipe Line it is treated in a stabilization plant at Kirkuk, which is designed to remove the high content of hydrogen sulphide. The stabilization plant has a capacity of about one hundred thousand barrels a day. It can produce low octane gasoline but does not produce kerosene or high octane aviation fuel. At the terminus of the pipe line at Haifa the British have

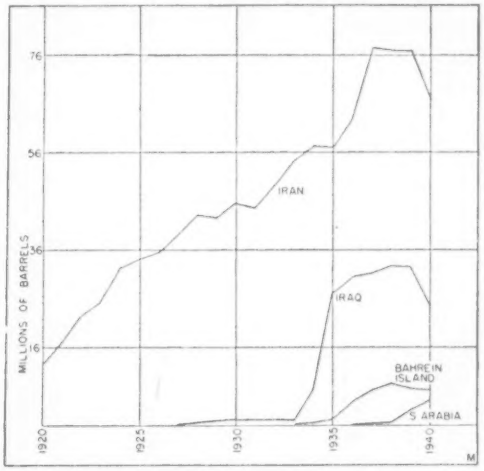


FIG. 2. PRODUCTION OF PEROLEUM FROM 1920 TO 1940 IN THE MIDDLE EAST.

constructed a refinery of forty thousand barrels daily capacity. At Tripoli there is only a loading dock. Within Iraq the production from Naft Khaneh and Chia Surkh is refined at Khanaquira (Aldwan). The refinery here has a capacity of about 2,500 barrels per day.

Saudi Arabia

The first oil concessions were granted in Saudi Arabia in 1935 to the Standard Oil Company of California, and geological exploration began immediately. The grant is located in El Hasa and has an area of 249,000 square miles, the approximate combined size of California and Oregon. After a number of wild-

cat wells were drilled, oil was discovered in 1936. The Dammam field is surrounded by desert, but as a result of abundant springs it has a number of magnificent oases. The greatest handicaps to the development of the field have been inadequate outlets and refinery facilities. On January 1, 1942, there were sixteen producing wells, with a daily potential yield of seven thousand barrels. The oil ranges from 35 to 50° A.P.I. gravity and comes from depths varying from 2,100 to 8,000 feet. Production has risen from a yearly total of twenty thousand barrels in 1936 to over five million barrels in 1941.

Test wells have yielded favorable returns in three other districts of Saudi Arabia. The Abu Hadriya district and the Maagola area about one hundred miles northwest of Dammam have given promising indications. The first well drilled in the Kingdom of Kuwait had a potential production of approximately 4,400 barrels a day from a depth of 3,500 feet. Production in each of these areas is shut in and development will begin only after pipe line and refinery facilities are constructed. With these facilities available production can be greatly increased.

Bahrein Island

Bahrein Island, for centuries renowned for its important pearl fisheries, has now become the center of a well-developed oil industry. Active exploration first began on Bahrein Island in 1932 after the Standard Oil Company of California had acquired the exploratory rights. The first well was completed in June 1932, producing 2,400 barrels daily at a depth of 2,008 feet. However, the first shipment of crude oil was not made until 1934. By 1936 sufficient production had been developed to demonstrate that the field was capable of sustained production over a large area, and in 1937 the drilling program was changed from straight exploration to partial development. The wells are large, a number having a potential production of twenty thousand to thirty thousand barrels a day. In recent years output has been restricted because of insufficient refinery capacity and inadequate transportation facilities. Only enough has been developed to supply the anticipated immediate demand for petroleum and to maintain a gas-oil ratio likely to give the maximum ultimate production rather than the maximum present production. The highest production came in 1938, with a yield of 8,298,000 barrels. Since the beginning of World War II many of the markets of Bahrein petroleum have been lost, so that production has fallen off considerably. Much work has been done on a repressuring system, and the arrangement of the compressors, controls and other features designed to thwart invasion will help to guard the oil resources of the field. Since the Sheik of Bahrein is assisted by a British political adviser, this territory has been bombed by Italian aircraft a number of times.

Construction of a refinery was begun in 1935 as soon as it was evident that production would justify the operation of a plant. Originally designed for ten thousand barrels daily capacity, the refinery facilities have been enlarged so that at present it has a daily capacity of 32,500 barrels. To aid in handling the refined oils a loading terminal was constructed on Sitrah Island, a short distance from the main island across shallow water. Pipe line connections run from the refinery to the terminal. At low tide the wharf will accommodate two tankers. The daily loading capacity ranges from 1,600 to 4,800 barrels, depending upon the product.

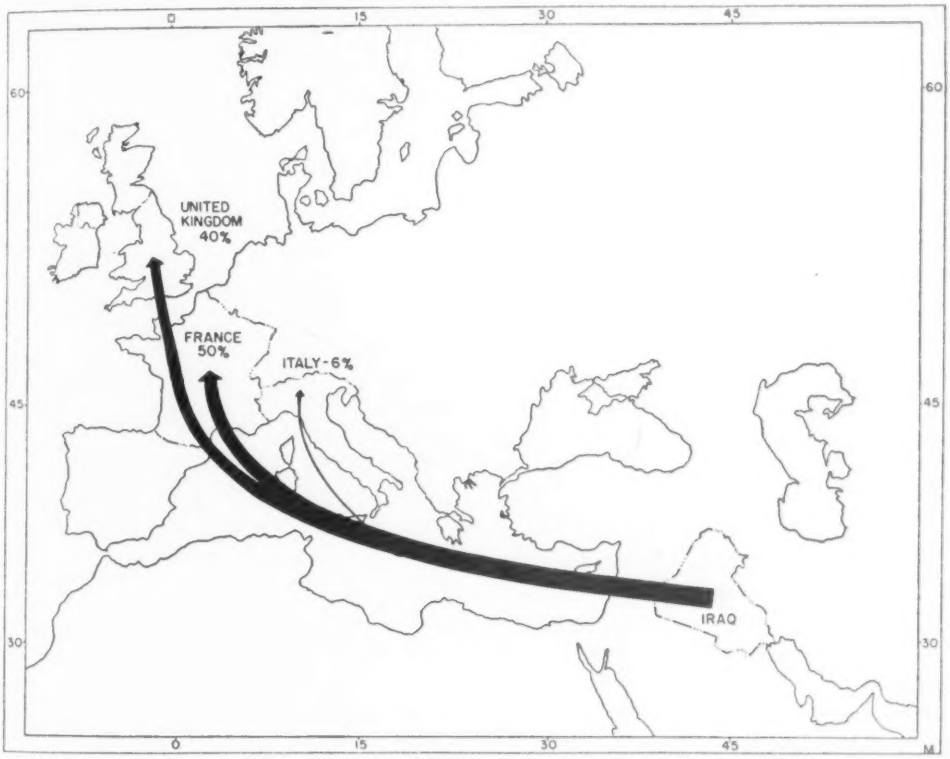
Egypt

Petroleum in commercial quantities was discovered in Egypt in 1911 at Hurghada, about two hundred and fifty miles south of Suez. Because of strin-

gent mineral laws there was little incentive for additional exploration or development, and so production remained small, usually under a million barrels a year. Finally, in 1936 the petroleum laws were liberalized, and both American and British companies increased their exploratory efforts. As a result in 1938 the Ras Gharib field, about midway between Suez and Hurghada, was discovered. Production in 1939 was this became the nearest source of petroleum and production increased. Two refineries located at Suez, one of seventeen thousand barrels daily capacity and the other fourteen thousand barrels, process the Egyptian oil.

Markets of Middle Eastern Petroleum

Since the Middle East consumes only a small percentage of its total produc-



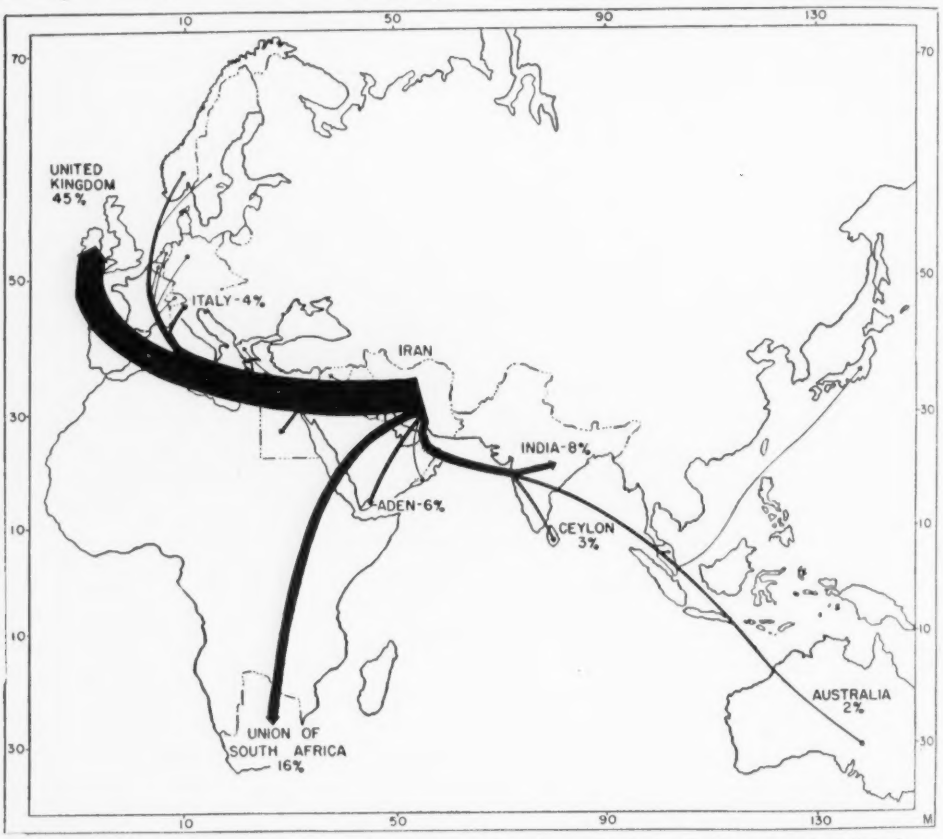
International Petroleum Trade, U. S. Department of Interior

FIG. 3. PRINCIPAL MARKETS FOR PETROLEUM EXPORTED FROM IRAQ, 1939
THE WIDTHS OF THE ARROWS INDICATE RELATIVE VOLUME OF PETROLEUM.

5,100,000 barrels, an increase of 207.19 per cent. above 1938. With the outbreak of the European War in 1939, a decline in output was caused by interruptions of tanker schedules, delay in delivery of equipment, and restrictions on civilian consumption in a number of countries served by Egypt. However, with the beginning of hostilities in North Africa tion, most of its petroleum must be exported. Production has always been controlled by market demands. In 1940 more than ninety per cent. of the oil of this region entered international trade. Petroleum-deficient Europe is normally the largest consumer of Middle Eastern petroleum, usually taking more than seventy-five per cent. of the total export.

The principal products exported are crude petroleum, fuel oil, gasoline and kerosene.

The petroleum of Iraq is marketed almost entirely in Europe (Fig. 3). France before the war was the largest consumer, taking more than fifty per cent. of the export. Since there was no refinery at the terminus of the Iraq Pipe Line at Tripoli, the oil was shipped in the crude state and was processed in France. The United Kingdom was the second largest purchaser, and the remainder went largely to the other countries of northwestern Europe. In 1939 Iraq exported the largest amount of petroleum since the beginning of exploitation. However, with the outbreak of the European War the Iraquan market was greatly restricted. When France capitulated in June 1940 the British sealed the French prong of the pipe line at Haditha. During the summer of 1940 the refinery at Haifa was bombed, and transport through the Mediterranean became exceedingly hazardous. As a result production had to be curtailed, and in 1941 declined to less than half that of 1939. With the defeat of the Axis forces in the Mediterranean during the summer of 1943, the Kirkuk field now supplies much of the petroleum used by the British and American fleets, and also furnishes supplies to the land forces in this region.



International Petroleum Trade, U. S. Department of Interior

FIG. 4. PRINCIPAL MARKETS FOR PETROLEUM EXPORTED FROM IRAN, 1939
THE WIDTHS OF THE ARROWS INDICATE RELATIVE VOLUME OF PETROLEUM.

Europe was also the largest market for the petroleum from Iran, Saudi Arabia

and Bahrein Island, but Africa and southern Asia were supplied from these fields as well (Fig. 4). Europe during peace took more than half of the petroleum products. The United Kingdom was the largest consumer taking more than seventy-five per cent. of the total amount going to Europe. The Union of South Africa was the second largest purchaser, and India was third. The beginning of the War in 1939 likewise caused a dislocation in these markets largely excluding the European area. However, this loss has been compensated by the new markets gained in the southwest Pacific since the oil fields of Burma and the East Indies have been captured by the Japanese.

The capture of the Middle Eastern oil fields would give to the Axis powers a large supply of petroleum, and their defeat would be infinitely difficult. Germany would no longer be dependent on the limited supplies from the Rumanian oil fields and the production of synthetic petroleum from coal. The Allied forces have repelled all drives toward this region, and the fields are now no longer threatened by invasion. The importance of oil has increased tremendously since World War I. Navies are now entirely fueled by oil, merchant fleets largely so. Planes and tanks are numbered by thousands instead of hundreds. Thus, this region with the greatest resources of petroleum in the Old World is one of the most important areas of the war.

Petroleum in the Economy of the Middle East

The oil fields of the Middle East have been developed by foreign companies, but the right to grant concessions is vested in the national governments. The concessions are granted for a long term of years for a fixed amount per acre and an established royalty on the oil production. Most of the countries have also demanded a minimum royalty regardless of production or receipts. The minimum annual royalty for Iran was set at three million dollars in 1932. This was of little importance before World War II, for the annual income from royalties was more than ten million dollars. However, with the loss of markets at the outbreak of war, oil revenue declined and the Iranian Government demanded a higher minimum royalty fee in 1940. The Anglo-Iranian Oil Company agreed to pay five million dollars to compensate for the loss of revenue during 1938 and 1939 and also promised to pay a minimum royalty fee of sixteen million dollars for 1940 and 1941. The greater part of the modern improvements and mechanization of the army has been made possible by means of the oil royalties. Modern industry has existed in Iran for less than fifteen years. The construction of cotton mills, sugar refineries and cement plants constitutes the most important industrial advancements. The development of the Iranian railroad system started in the early 1930's. The principal railway is the Trans-Iranian Railroad which bisects the country from north to south. In Teheran and the principal cities many of the streets have been widened and improved. A central lighting system was installed in 1936 in the capital; previous to this few facilities for electrification existed. The reclaiming of land by irrigation at Khuzistan is making available some hundred thousand acres for cultivation. The campaign to reduce illiteracy resulted in the opening of night schools for persons eighteen to forty years of age. These schools are compulsory for illiterate policemen and government officials. The foundation stones for the first Iranian university were laid in 1935.

Iraq has also directed her oil royalties to the improvement of the country. When oil exploitation began on a large scale in 1932, the Iraqi Parliament de-

cided to devote the royalties to internal improvements, and a special works program was established. The programs were scheduled in a series of three, four and five year capital works budgets, and the government secured a guarantee from the I.P.C. of at least a minimum of one million six hundred thousand dollars in annual royalties, in gold, to guard against price changes and quota arrangements. The oil revenue for 1939–1940 was over eight million dollars, or more than one-third of the total government receipts. One of the most important items in the program has been the reclaiming of land by irrigation. The Habbaniya Project, an example of such works, was completed in 1941. It consists of five channels from the Euphrates River near Baghdad to Lake Habbaniya. A series of regulation gates directs the overflow of the Euphrates floodwaters first into Lake Habbaniya and then onto the low-lying Abu Debbis depression to the south, where more than fifty thousand acres are being irrigated. Similar works on the Mississippi River are called floodways. The railroads of Iraq have been purchased from Great Britain, and in 1939 a program was initiated for completing the line between Barji, Tel and Kotchek, the only missing railway link between Europe and Basra on the Persian Gulf. This portion of the railroad was opened to traffic in the summer of 1940. Schools are being built, and a large number of students are sent abroad each year. Other expenditures have included the construction of roads, bridges, government buildings and similar works.

Along with government expenditures, the oil companies have spent considerable sums to better the working conditions of their employees and to improve transportational facilities for the general benefit of the countries. This program has aided the modernization of the region. Petroleum exploitation in the Middle East is still in the initial period, so that with increased development of the large reserves the future of the industry is bright, and the combination of natural resources and labor with foreign capital and operating experience promises the greatest benefits to the oil countries at lowest cost and minimum risk.

THE ADVENT OF MICROSCOPES IN AMERICA

WITH NOTES ON THEIR EARLIER HISTORY

By Dr. FREDERIC T. LEWIS

PROFESSOR OF COMPARATIVE ANATOMY, HARVARD MEDICAL SCHOOL

So gradual was the invention of the microscope, through accidents and strokes of genius—so unaware were the builders of this mighty engine of its latent powers—that uncertainty prevails as to its inventor and the date of the invention. In a famous book dedicated to the Senate and People of Middelburg, Metropolis of Zeeland, *Telescopii mater Inventrix*, Dr. Pierre Borel gathered affidavits to establish that Zacharias Jansen of that city was "the true inventor of the telescope."[1] "All nations have claimed it," he said, with some exaggeration. "In addition, he (Zacharias Jansen) invented the microscope as the following evidence will show." But as Zachary was a lad of about ten at that time, the evidence is inconclusive. His father, an optician in whose shop he learned the trade, presumably had a part in it; and another lens maker of Middelburg, which was noted for its glass works, applied for a patent. Borel observes "utque Deus viros miseros pro Apostolis accipere, sic etiam ex populi fæce ad hoc arcanum patefaciendum viros ignobiles eligere voluit."

In 1846, when the Elders of the Reformed Church at Middelburg sought to demolish the little house that was inhabited by Zacharias Jansen in 1590, "the government" permitted it only on condition that a stone tablet should mark the spot. It is inscribed in Dutch:—"Against this wall stood the house of Zacharias Janse, Inventor of the telescope in the year MDXC."[2]

At an unspecified date the Jansens gave the first recorded compound microscope to Prince Maurice, commander of the armed forces of the Netherlands. For that device they received some honorarium. "Much later, *viz.* in 1610," they presented him with a spy-glass, the construction of which was a military secret. A second and "similar microscope" the Jansens gave to the Austrian Archduke Albert, possibly in 1605 (according to Clay and Court[3]) when he came to Zeeland. Duke Albert passed it on to Cornelis Drebbel, mathematician, engineer and inventor, who took it to England. The general appearance of that instrument has been described by Ambassador Willem Boreel, to whom it was shown by his friend, Drebbel, in London, 1619. "It magnified little particles of dust or other tiny objects to an almost miraculous degree."

Meanwhile accounts or rumors of the Dutch invention had reached Italy, and Galileo made a compound microscope on similar principles (*i.e.*, with a biconcave eye-lens) in 1609. It is only by discrediting Ambassador Boreel's letter to Dr. Borel, dated July 9, 1655, as written a full half-century after the events it describes, that Professor Govi can consider Galileo to be the inventor of that form of compound microscope. Those who have given special attention to the early testimony, as Mayall finds—notably Van Swinden, Moll, Harting, and Poggendorff—are agreed that the invention must have been between 1590 and 1609;

[1] Petrus Borelius, *De vero telescopii inventore, etc.* Hagæ-Comitum, 1655. 2 l., 67 pp., 2 portr. Published with two separately paged additions, one dated 1656.

[2] A. J. van der Aa, *Biographisch Woordenbock der Nederlanden.* Vol. 9. Haarlem, 1860. pp. 95–96. The author is much indebted to Professor Taylor Starck for a translation of the entire article, "Janse (Zacharias)."

[3] Reginald S. Clay and Thomas H. Court, *The History of the Microscope.* London, 1932. pp. xiv, 266. (p. 9.)

and that among the Dutch claimants "the probabilities are slightly in favour of the Janssens."[4] But Professor Govi has truly remarked (in 1880, and again in 1888[5]) that "the glory of having reduced the *Keplerian* telescope to a microscope should rest with Drebbel. . . . The apologists of the Tuscan philosopher, by attributing to him the invention of the microscope without specifying with what microscope they were dealing, defrauded Drebbel of a merit which really belongs to him; but the defenders of Drebbel would act unjustly in depriving Galileo of a discovery which incontestably was his."

Not only did Drebbel so improve the microscope that Galileo, in 1624, on seeing his instruments, thought no more of his own *occhialino*, but it was Drebbel who introduced the compound microscope into England, and thus indirectly to America. "He did a great deal to make this instrument generally known all over Western and Southern Europe."

Drebbel was described as a handsome man, of gentle manners, though badly dressed and looking like a Dutch farmer. "I do not remember," said the painter Rubens, "ever to have seen a man of more extraordinary personal appearance than he." So one looks attentively at the little portrait on the title page of his "Short treatise on the nature of the elements" (in the Haarlem, 1621, ed.) reproduced by Dr. Tierie in his fascinating and well-documented biography.[6] In outline Drebbel's career, as presented by Dr. Tierie, is as follows.

Cornelis Drebbel (1572–1633) was born in Alkmaar in North Holland, and spent the first half of his life in his native land. Without formal education, he became a professional engraver, associated with the expert Hendrik Goltzius, whose sister he married in 1595. As an inventor he early took out patents for a pump, a time-piece and a chimney. In 1601 he was at Middelburg, constructing a fountain for the municipality. There he may have learned to make glass and grind lenses, of which arts he was later a master. In 1604 he published a small book *On the Nature of the Elements, and how they bring about wind, rain, lightning, thunder and why they are useful.* It was translated into several languages and there were many editions. Shortly thereafter he moved to Eltham, a suburb of London, where he set up a perpetual motion device—a sort of air thermometer, rising and falling with the daily temperature rhythm. All England knew of it. Among other references, Dr. Tierie cites Ben Jonson's *Silent Woman* (1609, Act V. Sc. 3), where the distraught husband exclaims,—"My House turns round with the Tumult . . . The Perpetual Motion is here, not at Eltham!"

Drebbel entertained King James I with his inventions, which included a self-playing clavichord; and he was appointed tutor of the Prince of Wales. Rudolf II, Emperor of Germany, invited him to Prague, where he spent three years (1610–1613). There he made gold alloys for the German mint, and demonstrated his *"Perpetuum mobile."* Gali-

[4] John Mayall, Jr., "The Microscope." Cantor lecture 1. *Jour. Soc. of Arts*, 1886, vol. 34, pp. 987–997. (p. 992.) Also Alfred N. Disney, *Origin and Development of the Microscope. An Historical Survey.* London, 1928. pp. xii, 303. (The evidence is reviewed at length, pp. 89–108.) Also Charles Singer, "Notes on the Early History of Microscopy," *Proc. Roy. Soc. of Med.*, 1914, vol. 7, Sect. on Hist. of Med., pp. 247–279. (p. 256: "Zacharias, miscalled Jansen," since there was no family name.)

[5] Gilberto Govi, "Nuovo documento relativo alla invenzione dei Cannocchiali Binocoli." *Bull. d. Bibliografia e d. Storia d. Sci. Mat. e Fis.*, 1880, vol. 13, pp. 471–480. Also: "Il microscopio composto inventato da Galileo." *Atti R. Acad. Sci. Fis. e Mat., Napoli*, 1888, ser. 2, vol. 2. A complete anonymous translation of the latter, "The Compound Microscope Invented by Galileo," is found in *Jour. Roy. Micr. Soc.*, 1889, Pt. 2, pp. 574–598.

[6] G. Tierie, *Cornelis Drebbel (1572–1633).* Amsterdam, 1932. pp. viii, 124. The writer has quoted this admirable biography *ad libitum.*

leo was informed of it by Ambassador Guglio de Medici; and in 1612 Antonini sent him, from Brussels, a full description of the device.

When Drebbel returned to England, he had been given, as already noted, the Jansen microscope which he demonstrated to Boreel in 1619. In 1620 he visited Zacharias Jansen in Middelburg, no doubt discussing the production of microscopes and telescopes. A year later there were to be seen, at his house in London, microscopes of the new pattern, with the biconvex eye-lens. Constantyn Huygens, of the Dutch legation, father of the famous physicist, Christiaan Huygens, wrote in his autobiography,—"Even if he should prove to have achieved nothing else in his whole life, this wonderful glass gives him a right to an immortal name." In 1629 Rubens said in a letter,—"They assure me, in sooth, that for many years he has made nothing but that optical instrument, the tube of which stands up straight, and that objects placed under this are exceedingly much enlarged."

About 1620, two young Dutchmen living in Germany—Abraham Kuffler and his younger brother Jacob—"having only very slender means of subsistence" came to England, hoping to be rewarded by King James for a book they had written. "But the King did not trouble himself in the least about the book." Then they visited Drebbel, and realizing the advantages to be enjoyed could they but gain his favor, they both decided to try to win the hand of his daughter. "He whom she should love most should marry her." Thus Dr. Tierie translates de Peiresc's instructive letter. "The plan succeeded; the girl preferred the one who was not learned (this was Abraham) because he was handsomer in appearance; he proposed to her and married her, he and his brother helping Drebbel with all possible zeal and energy."

"In the spring of 1622 (before the wedding had occurred) Drebbel sent Jacob Kuffler to demonstrate and sell the new microscopes on the Continent. On May 22 Jacob gave a demonstration in Paris in the apartments of Maria de Medici, the Queen-Mother, who was much interested in optical instruments. De Peiresc[7] was present, and was immediately seized with great enthusiasm for the new invention."

Within a fortnight de Peiresc had obtained one of the microscopes for himself, and his manuscript description of it is regarded by Dr. Tierie, who quotes it in full, both in the original French and in English translation, as "the first complete and very accurate description of a microscope that we possess." De Peiresc gave Jacob Kuffler letters of introduction to his brother in Aix, and to others in Rome, who might obtain for him audience with the Grand Duke of Tuscany and with Cardinals di Santa Susanna and Barberini (later Pope Urban VIII). King James, Prince Maurice, and the Duke of Anjou (brother of the King of France) had already been provided with the Drebbel microscopes. But poor Kuffler died of the plague in Rome before he could show "the marvellous effects of his *occhiale.*" How de Peiresc succeeded in transmitting a microscope to Cardinal di Santa Susanna in 1623 is told by Professor Govi. They had trouble in setting it up, but in May of 1624, Galileo chanced to visit Rome and

[7] Nicolas Claude Fabri de Peiresc (1580–1637), Senator of Aix, wealthy man of letters and patron of science, prepared "un grand nombre de traités sur toutes sortes de sujets." He studied the development of the chick with Fabricius, and demonstrated human lacteals by having a condemned criminal well fed before hanging and promptly brought to the Anatomick Theatre (1634). Gassendi published his *Vita*, 1655; Englished by W. Rand, 1657. His obsequies were issued in Carmina in 40 languages entitled *Panglossia* (Rome, 1638). "The prodigious *Learning*, wherewith some great Literators have been enriched!" is Cotton Mather's comment thereon.

showed them how to manipulate it. De Peiresc was pleased that Signor Galileo understood it; though even so, they did not obtain "as clear an effect as it gives in its proper adjustment."

With Drebbel's later history we are hardly concerned. He had developed a submarine, open below, in which "he calmly dived under the water, while he kept the king and several thousand Londoners in the greatest suspense—for three hours as rumour has it." It carried 24 people, could travel a few miles, and was provided with air freshened, apparently, with oxygen derived from saltpetre. The depth was determined by a mercury barometer. Since "it is not hard to imagine what would be the usefulness of this bold invention in time of war" (as Huygens wrote in 1631), Drebbel — a non-resistant anabaptist — was employed by the British Admiralty, for whom he made floating mines to set fire to the French fleet. Before La Rochelle, one of them took effect, throwing water into the ship "with much power; all the others were captured as they floated on the water and did no harm." "Some laughed at King James, saying that this everlasting inventor has never achieved anything the cost of which has been covered by its usefulness," and late in 1628 Drebbel was dismissed from the service.

"He was very poore, and in his later time kept an Ale-house below the [London] bridge." Two other Kuffler brothers had come to England, one of whom, Dr. John Sibertus Kuffler (M. D., Padua, 1618; "Physician to the Duke of York") married Drebbel's second daughter, Catherina. After Drebbel's death, in Trinity Parish, London, 1633, Dr. and Mrs. Kuffler sought to perpetuate and develop his discoveries. There were devices for the army and navy, thermostatic incubators, a camera obscura of service to artists, and the tin-mordanted cochineal—"the lovely colour"—known all over Europe as the finest scarlet dye. "The Drebbel microscopes were now well known and were being made in Holland, England, France and Italy."[8] Hooke's microscopes, it is said, were developed from the Drebbel pattern. As a "deservedly famous Chymist" Drebbel was known to Boyle—Pepys, Evelyn, Digby and Wren also have referred to him—and his influence extended to America.

John Winthrop, Jr. (1606–1676), the first American colonist to be elected to the Royal Society, had among his books a small duodecimo containing two works by Basil Valentine,—*Von den naturlichen und obernaturlichen Dingen*, 1624, and *De occulta philosophia*, 1603. On the fly leaf, penned and signed by Winthrop, is the note,—"This was once the booke of that famous philosopher and naturalist, Cornel. Drebbel, who usually carried it with him in his pockett and after his death was given me by his sonne-in-law, Mr. Abram Keffler."[9]

Among the Winthrop papers is a letter from Abraham Kuffler, dated London, June 12, 1639, in which he admits that,

> . . . sseeing all Christendome in armes, and all kings and princes tacken that waye, I was forst to leaffe off all curious inventissions. I now onely follow dieing of scarrlett, in which I have so much to doe that I can follow nothing elles. . . .[10]

Two letters from Dr. John Kuffler, in 1660 and 1662 respectively, continue the friendly correspondence, perhaps hoping for financial aid from Winthrop's "rich mine" in Connecticut.

Between 1661 and 1663 John Winthrop was in England, primarily to obtain a charter for Connecticut, and by his winning personality and influential friends he secured "the most liberal

[8] Clay and Court, *loc. cit.*, p. 12.

[9] C. A. Browne, "Scientific Notes from the Books and Letters of John Winthrop, Jr." *Isis*, 1928, vol. 11. pp. 325–342. (p. 329.)

[10] *The Winthrop Papers*, Part 3. Coll. Mass. Hist. Soc., 5th Ser., vol. 1, 1871. (pp. 270–271.)

charter that had yet been granted to any colony." He was elected Fellow of the Royal Society in 1663, and came home with a telescope, with which, on August 6th, 1664, he thought he observed a fifth satellite of Jupiter.[11] There was a general interest in astronomy in the colony, and when, in 1672, he gave a telescope to Harvard it was enthusiastically acknowledged. Although Winthrop had abundant opportunity to hear of microscopes and to obtain one, there is no record that he did so. In 1663, the year of Winthrop's election to the Royal Society, Monsieur Monconys, of Lyons, came to London. He was traveling everywhere in search of novelties in apparatus, and curiosities in chemistry.[12] Already he had a compound microscope with four lenses, of which he has given a diagram and full specifications. He visited Dr. Kuffler, who "works at chemistry all the time, but in which he has found nothing new." Monconys bought some lenses of a maker opposite the Exchange, but not the best, as Sir Kenelm Digby told him, recommending one named Bailey, at St. Paul's cemetery. "He directed me also to Mr. Reeves of Long Acre, who makes excellent microscopes." Soon afterwards, Monconys visited Boyle with whom he talked physics chiefly, but he noted that Boyle had a very good telescope, and two excellent microscopes, "qui surpassoient en grosseur les miens, mais non pas en clarté." Boyle, he said, examined the texture of ox eyes by freezing them, naturally in winter, artificially in summer, after which he cut them easily with a penknife. At Sir Christopher Wren's house he saw that famous architect's original draughts of insect parts, made with the microscope, which well nigh discouraged Robert Hooke from proceeding with his own *Micrographia*. In short, London teemed with microscopy when John Winthrop returned to Connecticut. He might have brought the microscope of which we first hear twenty-two years later, in the Mather family, which was on very friendly terms with the Winthrops, but that is a remote possibility. Cotton Mather (1663–1728) who was born in Boston, and who never traveled "farther, perhaps, than New Haven,"[13] has very indirectly made known that he owned and used a microscope in 1685. Where it came from and what sort it was, he has never specified; and yet these are matters of some interest in view of the *possibility* that it was the first in America.[14]

"Cotton Mather, the New England Puritan divine, is generally considered a rather grotesque pedant," writes William James in his *Varieties of Religious Experience*, "yet what is more touchingly simple than his relation of what happened when his wife came to die?"[15] "A typical infant prodigy grown up,"

[11] Frederick E. Brasch, "The Royal Society of London and Its Influence upon Scientific Thought in the American Colonies." *Scientific Monthly*, 1931, vol. 33, pp. 336–355, 448–469. (pp. 341–2.)

[12] Balthasar Monconys (1611–1665), *Journal des Voyages . . . Où les Savants trouveront un nombre infini de nouveautez*, etc. En trois parties. Lyon, 1665 et 1666. (His own microscope is described in Part 1, pp. 122–128 (see also Disney, *loc. cit.*, p. 109): his visit to England, Part 2, pp. 11, 40, 45 *et al.*)

[13] Thomas J. Holmes, "Cotton Mather and His Writings on Witchcraft." Papers of the Bibliographical Soc. of America, 1926, vol. 18, pts. 1 and 2. 29 pp.

[14] The New York Academy of Medicine has a microscope on the case of which is a brass plate inscribed: "This Microscope brought from Holland by Jan Evertson Keteltas in the year 1649 is given by his Descendent Henry Keteltas, Aug. 12th 1895 to Doctor Warren Coleman as a pleasant remembrance." The case belongs with, and contains, a Culpeper tripod microscope, made by Benj. Cole of London, who began independent business in 1751. (See Bull. N. Y. Acad. Med. 1930, vol. 6, pp. 740–742). Nevertheless the unverified report was given wide circulation (*Jour. Am. Med. Asn.*, 1930, vol. 95, p. 1921: *Science*, 1931, vol. 73, p. 10). When microscopes were first brought to New York is apparently still an open and an interesting question.

[15] William James, *The Varieties of Religious Experience*. London, 1902, pp. xii, 534. (p. 303, where the passage from Mather is quoted.)

is Morison's later judgment, "pedantic and conceited, meddlesome and tactless."[16] Worst of all, he is held accountable for the score of Salem witchcraft executions. "No one was more active in fighting the Devil's works as revealed in witchcraft: no one for well on to two centuries, has borne so much of the odium of what was done as he."[17] Yet the first hanging for witchcraft in Boston occurred nearly fifteen years before he was born. The Court sought to obey the command: *Maleficos non patieris vivere* (Thou shalt not suffer a witch to live: Exodus 22:18).

The guilt was not all Mather's, nor in that parallel tragedy was Calvin solely responsible for the burning of Servetus. Where the stake once stood, "duteous and grateful followers of Calvin, our great reformer" have erected an expiatory monument "condamnant une erreur qui fut cela de son siècle." "Give the devil his due, John Calvin was a great man," said Bishop Berkeley.[18] For Cotton Mather, also, such is the only line of defence.

Mather published too much, and said so. "A Great Fault . . . I *do* confess, That I have written too many Books, for one of my small Attainments" (*Winter-Meditations*, 1693). No less than 437 published works, exclusive of reprints, prefaces, and unprinted manuscripts, have been counted. "Be Brief" was the placard which Franklin saw in Mather's study, when he called there in 1724, and received other useful counsel. Two of Mather's early publications are in verse. We are not concerned with his "Poem" in memory of President Oakes of Harvard College, Boston, 1682, but only with "An Elegy on the much-to-be-deplored death of that never-to-be-forgotten person, the Rev. Mr. Nathanael Collins," Boston, 1685. The Rev. Mr. Collins (A.B., Harv. 1660) was the first minister of a church in Middletown, Conn., with a meeting-house 20 feet square, 10 feet from sill to plate, and enclosed in palisades against the Indians. The Elegy includes the following stanza and footnote:—[19]

I would that you, my Friend, each *drop* of Ink
Could fill with *Elogyes* no fewer then
The little *eels** that may swim in't: I think
They all should celebrate this *Flow'r of men.*

* *of which I can with my* Microscope *see incredible hundreds playing about in one drop of water.*

Can a punning consonance of eel and elegy have been intended? (Certainly so, if O. W. Holmes had written it!) But the microscopist is not familiar with myriads of eels in a drop of *water*. The incredible hundreds of eel-like forms occur in a different fluid, as Leeuwenhoek had made known to the Royal Society; and Mather, who read everything, was surely aware of it. For reasons which led Hoole to omit all reference to spermatozoa in his voluminous *Select Works of Leeuwenhoek* (London, 1800), Mather may have preferred to refer to the denser fluid as water. In his *Christian Philosopher* (London, 1721, p. 151) Mather states that "Mr. *Derham*, in a *Drop* of the *green Scum* upon Water, a *Drop* no bigger than a Pin's-head, sees no fewer than an hundred [little Insects] frisking about. How vastly many more in a *Drop* of *Pepper-water!* How vastly many, many, many more, in a Drop of the *Leuenhoe-*

[16] Samuel Eliot Morison, *Harvard College in the Seventeenth Century*. Cambridge, 1936. Part 1, pp. xxii, 360; Pt. 2, pp. xviii, 361–707. (p. 503.)

[17] Barrett Wendell, *Cotton Mather, the Puritan Priest*. New York (no date): reprint, Cambridge, 1926, pp. viii, 321. (p. 100.)

[18] Noah Porter, *The 200th Birthday of Bishop George Berkeley*. New York, 1885. pp. vii, 84. (p. 44.)

[19] Reprinted in The Club of Odd Volumes. III. Early American Poetry. A Poem and an Elegy. By Cotton Mather. Boston, 1896. With an instructive preface by James F. Hunnewell. The writer is greatly indebted to Mr. Frederick G. Kilgour for discovering for him this important reference to the microscope (p. 5 of the Elegy) and for other valued notes.

kian Examination!" This circumlocution tallies with the Puritan's recognition that the sexual stimulus is sufficient without aphrodisiacs; its superabundant appeal should be quieted through modesty in dress, decency in books and drama, and much else derided as puritanical. "There should be in our Praises an Amputation of all that is improper."

The preceding quotation is from "The Wonderful Works of God Commemorated: a Thanksgiving Sermon" by Cotton Mather, delivered in Boston, Dec. 19, 1689, and published in 1690. In that also, Mather refers to his personal observation with the microscope:

> And the *Little* things which our Naked Eyes cannot penetrate into, have in them a *Greatness* not to be seen without Astonishment. By the Assistance of *Microscopes* have I seen Animals of which many Hundreds would not Æqual a Grain of Sand. How Exquisite, How stupendous must the Structure of them be! The Whales . . . methinks . . . are not such Wonders, as these minute Fishes are.[20]

Cotton Mather was always deeply interested in medicine. In his Diary he records the birth and death of his first son as follows:[21]

> On March 28 [1693] Tuesday, between 4 and 5 A. M. God gave to my Wife, a safe Deliverance of a *Son*. It was a child of a most *comely* and *hearty* Look. . . . But the Child was attended with a very strange Disaster; for it had such an obstruction in the Bowels as utterly hindred the passage of its Ordure from it. Wee used all the Methods that could be devised for its Ease; but nothing wee did could save the Child from Death. It languished, in its Agonies, till Saturday, April 1 about 10 h P. M. and so dy'd, *unbaptised*. . . . I did not suffer such a Discomposure in my Thoughts, as to hinder mee, from preaching both parts of the Day following. . . . On the Monday, the Child was buried, with a very numerous and honourable Attendance of my Neighbours; and on one of the Grave-stones, I wrote only that Epitaph, Reserved for a Glorious Resurrection.
>
> When the Body of the Child was opened, wee found that the lower End of the *Rectum Intestinum*, instead of being *Musculous* as it should have been, was *Membranous*, and altogether closed up. I had great reason to suspect a *Witchcraft* in this praeternatural Accident; . . . However, I laid little *Stress* on this Conjecture.

Later in 1693, Mather published his *Winter-Meditations*, in which there is a brief passage quite similar to that already cited from his "Thanksgiving Sermon." But instead of asserting "have I seen," the reference is merely to what "our microscopes" reveal. "As for our Bodies," he reflects, "What a sad thing it would have been, if these had been monstrously *Deformed*, or *Defective* in any One of all their *Members*. Truly, There are Thousands of *Mercies* and *Wonders*, in one *perfect* Child!"

Meanwhile (in 1692) Cotton Mather's father, the Rev. Increase Mather, President of Harvard, had returned from England bringing a new telescope for the College. He had spent many hours with Robert Boyle, and visited John Flamsteed, Astronomer Royal, to view the stars;[22] but there is no record of any microscope purchased, or of any collegiate interest in microscopy. Thus Cotton Mather's book of 1721, *The Christian Philosopher*, becomes the more notable. Its first half, indeed, is devoted to astronomy and the inorganic world; but in the final 72 pages there is a résumé of gross and microscopic observation of animals and plants, astonishing in scope and penetration. Everyone seems cited, —Grew, Malpighi, Leeuwenhoek, Cesi as discoverer of "seeds" in ferns, Kircher as to vermiculated blood, Bellini on the tubes and siphons of the kidney, Dr. Mead observing with the microscope a parcel of small salts in the poison of the viper. "We will not meddle with the Controversy between *Etmuller* and *Wil-*

[20] This passage has been cited by Theodore Hornberger, in "The date, source, and the significance of Cotton Mather's interest in Science." *American Literature*, 1934, vol. 6, pp. 413–420.

[21] "Diary of Cotton Mather," 1681–1708. Coll. Mass. Hist. Soc., 1911, 7th Ser., vol. 7, pp. 1–604. (p. 163.)

[22] Kenneth Ballard Murdock, *Increase Mather, the Foremost American Puritan*. Cambridge, 1925, pp. xv, 442. (pp. 264–5.)

lis, whether the *Vesiculæ* of the *Lungs* have any muscular Fibres, or no."

There is indeed great dependence on his library—which was a large one, he thanked the Lord (ultimately nearly 4,000 volumes)—rather than on direct observation. Yet, according to Zirkle, the *Christian Philosopher* contains the earliest published account of plant hybridization yet found.[23] Another personal observation concerns the passenger pigeon, now extinct:—"One Man has at one time surprized no less than *two hundred dozen* in his Barn, into which they have come for Food, and by shutting the door, he has had them all." Anticipating John Hunter,[24] he continues (p. 192):

> The *Cocks* take care of the *young* ones for one part of the day. . . . In the Crops of the *Cocks,* we find about the quantity of half a Gill of a Substance like a tender *Cheese*-Curd: the *Hens* have it not. This *Curd* flows naturally into their *Crops,* as *Milk* does into the *Dugs* of other Creatures. The *Hens* could not keep their *young* ones alive when first hatched; but the *Cocks* do fetch up this *thickned Milk,* and throw it into the Bills of their *young* ones, which are so nourished with it, that they grow faster, and fly sooner than any other Bird among us. None but the *Cocks* which have young ones to care for, have this *Curd* found in their *Crops.*

The crowning service of Cotton Mather came in 1721, in combating an epidemic of smallpox. That story is a familiar one. With his father's approval, he advocated inoculation and called a conference of physicians. "Only one, Dr. Zabdiel Boylston, had the courage to make the trial." On June 26, Boylston inoculated his 6-year old son Thomas, and two of his negro slaves, a grown man and a boy, all successfully. Though the town was horrified, the practice spread, defended by the Mathers as the means "for the saving of many a life."[25]

The microscope reached Canada (if our information suffices) by a very different route, sponsored by the Académie des Sciences de Paris instead of the Royal Society of London. Michel Sarrazin (1659–1735), who was born at Nuit-sous-Beaume, Burgundy, arrived in Quebec in 1685, accompanying a detachment of marines as surgeon.[26] He was at once a busy and successful practitioner. In fact, hospital appointments, accidents, duels, and the siege of Quebec furnished him an "assez vaste pratique." Then, after a severe illness in 1692, he thought of entering the priesthood—his brother was a priest—but, as the Abbot Tremblay regretfully found, the surgeon had not yet acquired "cette latitude de coeur qui nous fait reposer amoureusement en l'aimable providence de Dieu." Instead, Sarrazin returned to France, in 1694, for three years of study in *medicine.* They were spent in Paris, where the active Academy and the flourishing Jardin des Plantes awakened in him new interests. But he went on to Reims to receive the doctor's degree in medicine, returning to Quebec in 1697 at the urgent call of his clientèle.

In 1699 Sarrazin became "corresponding member" of the French Academy,

[23] Conway Zirkle, "More Records of Plant Hybridization before Koelreuter." *Jour. of Heredity,* 1934, vol. 25, pp. 1–18. (Wherein Mather's letter of 1716 is published for the first time; yet the changes in the *Christian Philosopher* version of 1721—"my two mites . . . a couple of experiments." (pp. 124–5)—are but slight.)

[24] John Hunter, *Observations on Certain Parts of the Animal Œconomy.* London, 1786. "On a Secretion in the Crop of Breeding Pigeons, for the Nourishment of Their Young." (pp. 191–197, 2 pls.)

[25] *"Several Reasons Proving that Inoculating or Transplanting the Small Pox is a Lawful Practice. . . ." By Increase Mather. "Sentiments on the Small Pox Inoculated." By Cotton Mather.* Reprinted from the original folio single sheet printed at Boston in 1721. With an Introduction by George Lyman Kittredge. Cleveland, 1921.

[26] Arthur Vallée, *Michel Sarrazin, sa vie, ses travaux, et son temps.* Quebec, 1927. p. viii, 291, including an important appendix of letters and documents. This "brilliant study" has been freely used by the writer: it is reviewed at length by Dr. Maude E. Abbott, *Canadian Med. Assoc. Jour.,* 1928, vol. 19, pp. 600–607.

and the distinguished botanist, Pitton de Tournefort, was assigned to receive his first communications. In 1700 the king at Versailles, in recognition of his experience and ability, appointed him "Médicin des hôpitaux de la Nouvelle-France." In that year Sarrazin sent to Tournefort a description of the anatomy of the beaver, in which he states, —"Si on considere ce poil [the coarser hair] avec un Microscope, on remarque dans son milieu une ligne beaucoup moins opaque que les côtez, ce qui fait conjecturer qu'il est creux."[27] There is no further reference to the microscope in that paper; and the stomach, which was rather carefully examined, is said to have no glands, although the lining of certain localized vesicles "paroît glanduleux." The publication of American observations in the field of microscopic anatomy may have begun with that note of Sarrazin's on the apparently hollow hairs of the beaver.

In 1702, as recorded in the Annales de l'Hôtel-Dieu, smallpox, brought by an Indian, spread like wildfire through Quebec, sparing not a house. Mortality was such that the priests could not bury the dead, nor attend the dying. Without ceremony bodies were brought daily to the cathedral, and in the evening were buried—sometimes 15 or 18 together. That lasted several months, so that the deaths in Quebec exceeded two thousand. Since fewer died in the hospital than in the town, it was filled to capacity.

[27] "Lettre de M. Sarrasin touchant l'anatomie du Castor." *Histoire de l'Acad. roy. des Sci.*, Paris, Année 1704, pp. 48–66. (p. 48) Sarrazin's "microscope" was a poor lens (see below), held in the hand toward a sun-illumined object, and Vallée suggests that he had "apparently borrowed it from the Jesuits." Christophorus Scheiner, S.J. (1575–1650) made a Keplerian microscope prior to 1626 (cf. S. H. Gage, *The Microscope*, 17th ed. 1941, p. 561); and Father Kircher, S.J. (1602–1680) was a renowned microscopist. Could their influence and example have extended to America?

Dr. Sarrazin's next paper was delayed. It dealt with the muskrat, called by the Indians the younger brother of the beaver. It was a serviceable study,[28] illustrated by the author, but contained nothing microscopic. In fact Sarrazin was embarrassed by his inability to find any connection between the epididymis and testis, which were rather widely separated. Réaumur, who was Sarrazin's correspondent after the death of Tournefort, told him that Winslow questioned his observations. Others challenged the statement in his third paper (on the porcupine)[29] that the quills seen "au Microscope" had a screw-like filamentous tip, just below which they were retrorsally barbed. "You astonish me, Sir," wrote Sarrazin in reply, "for you are equipped with all the necessary means for easily settling the matter, whereas I have only a lens which is not a good one. Poor as I am, I can scarcely obtain the instruments needed to reveal structures that can not be seen." So the Academy sent him "une loupe qui grossise considérablement" and one of the best injection-syringes obtainable, which he acknowledged in a letter of Oct. 10, 1727. At the same time Sarrazin said that he had decided not to dissect a skunk, because of the poisonous stench. As to the penetrability of the porcupine quills he informed the Academy that a hunter, named d'Orval, shot a young bear that had met a porcupine. Carrying the bear on his shoulders, as a shepherd does a sheep, a porcupine quill entered the back of his neck. After five years of debility, the hunter found the quill emerging from the front of his body. On extraction there was immediate improvement, and an ultimate return to perfect health. Some quills, Sar-

[28] "Extrait de divers memoires de M. Sarrazin sur le rat musqué." *Hist. de l'Acad.*, Paris, Année 1725. pp. 323–345. Pls. 11–14.

[29] "Observations sur le porc-épic." *Hist. de l'Acad.*, Paris, Année 1727. pp. 383–395.

razin observed, lacked the barbs and perforatorium, being perhaps only partly developed. His final description of the tips seems to be that they are rough "like a rasp or rat-tail file."

Since no distinction is made between "loupe" and "microscope" in Sarrazin's researches, and the instrument is not described, it may have been a simple lens which the Académie sent him in 1727, or a more elaborate apparatus. In the hospital wards in 1734, the doctor contracted a malignant fever, of which he died two days later. His monument is the genus *Sarracenia*, based upon one of the many Canadian plants that he sent for cultivation to the Royal Garden in Paris.

In 1732, Harvard College received from Thomas Hollis, of London, the gift of a Wilson "screw-barrel" microscope, with a hint that it was time for the college to use it.[30] It was presumably a simple microscope, with a second lens as a condenser. Little was done with it, however. It was available in the undergraduate years of Edward Bromfield (1723/4–1746) of the class of '42, who became more interested in such apparatus than his distinguished professor, the mathematician and astronomer, John Winthrop, F.R.S. (1714–1779). For on graduation, Bromfield, with Newton's *Opticks* and Hooke's *Micrographia* as guides, apparently both bought and made microscopes, "most accurately grinding the finest glasses." That he made and used them successfully is known by the merest chance. His pastor, Dr. Thomas Prince, saw him demonstrate a solar microscope at the Bromfield home in April, 1744, and was so impressed that he took notes, and published details of the display in his obituary notice of the young inventor.[31] For Bromfield died at the early age of twenty-two. The story is briefly told in the *Memorial History of Boston*, where the Greenwood painting of Bromfield, pointing with pride to a microscope of the Culpeper type, has been reproduced.[32]

Adjoining the Bromfield estate on the top of Beacon Hill was the Bowdoin mansion, and James Bowdoin (1726–1790) the future governor, and the first president of the American Academy,[33] must have known what his neighbor Edward, of about his own age, was doing with his microscopes. Bowdoin became interested in the phosphorescence of sea-water dashed by the oars. In a letter to Benjamin Franklin,[34] Nov. 12, 1753, he rejected the idea that it was due to particles of putrid fish and suggested that "the said appearance might be caused by a great number of little animals, floating on the surface of the sea, which, on being disturbed, might, by expanding their fins, or otherwise moving themselves, expose such a part of their bodies as exhibits a luminous appearance, somewhat in the manner of a glow-worm or fire-fly. . . .

[30] Frederic T. Lewis, "The Hollises and Harvard." *Harv. Grad. Mag.*, 1933, pp. 107–120. (pp. 109–110.)

[31] Thomas Prince, "Letter to the Publisher." *Amer. Mag. and Hist. Chron.*, Nov. 30, 1746, vol. 3, pp. 548–551.

[32] Justin Winsor, editor. *The Memorial History of Boston.* Boston, 1880–81. Notice of Edward Bromfield, vol. 4, pp. 509–510; portrait, p. 509. The original painting, formerly attributed to Smibert, is now in the corridor of the Department of Anatomy, Harvard Medical School, as part of a collection of mementos of Harvard microscopists, gathered by the writer over a number of years. Utilizing this exhibit without acknowledgment or perfect accuracy, Dr. B. Earl Clarke, in his paper "The History of the Microscope" (*R. I. Med. Jour.*, 1942, vol. 25, pp. 131–139) states that Cotton Mather "tells about seeing animalcules in ink" (!) and that Holmes passed around his demonstration microscopes "within a box" (!). The meager Bromfield records and papers are all on display. Unfortunately not any of his microscopes have been preserved.

[33] See Brasch, *loc. cit.* (in footnote 11), pp. 461–3.

[34] Jared Sparks, editor. *The Works of Benjamin Franklin.* Vol. 6, Boston, 1838. pp. 190–192. Bowdoin's letter "Concerning the Light in Sea-Water" was read at the Royal Society, Dec. 6, 1756. Franklin's reply is in vol. 5 of the *Works*, 1837, pp. 337–339.

There is no difficulty in conceiving that the sea may be stocked with animalcula for this purpose, as we find all nature crowded with life." (Although Harvard College received from him "a valuable microscope" in 1758, Bowdoin has been altogether reticent about having used one in this or other connections.)

Dr. Franklin replied on Dec. 13, 1753:

> The observation you made of the sea water emitting more and less light, in different tracts passed through by your boat is new; and your manner of accounting for it ingenious. It is indeed very possible, that an extremely small animalcule, too small to be visible even by the best glasses, may yet give a visible light. I remember to have taken notice, in a drop of kennel water, magnified by the solar microscope to the bigness of a cart-wheel, there were numbers of visible animalcules of various sizes swimming about; but I was sure there were likewise some which I could not see, even with that magnifier; for the wake they made in swimming to and fro was very visible, though the body that made it was not so.

Microscopes had at last become common in America. The foregoing notes, derived from a very incomplete examination of records locally available, are subject to revision—perhaps radical revision. The story of the coming of the microscope to other cities and colleges than those mentioned, is admittedly of equal or greater interest. When all the data have been gathered, some future writer may supply a forgotten page in American history.[35]

[35] Since the preceding paper was submitted for publication (September, 1942) Prof. Lorande L. Woodruff has described "The Advent of the Microscope at Yale College," *American Scientist*, July, 1943, vol. 31, pp. 241–245. He finds that "there was but one microscope at Yale until 1789," but that one was a Culpeper, purchased for the Trustees on May 19, 1734, of the London optician, Mr. Scarlet (perhaps "that excellent workman, Mr. Scarlet, *jun.*"—see *Phil. Trans.*, 1736, vol. 39, p. 260). This relic is "still in usable condition," and appears to be the first *compound* microscope definitely known to have been acquired in America.

GROWTH AND CHARACTERISTICS OF INDIA'S POPULATION

By S. CHANDRASEKHAR

NEW YORK, N. Y.

EVERY day India adds to her population the equivalent of a town of almost fourteen thousand inhabitants. This means that India's population increases every year by at least five millions. According to the census taken on March 1, 1941, India's population was 388,800,000. Today it must have reached the mark of four hundred millions. At this rate, according to some calculations, India may reach the staggering figure of seven hundred millions by 2001 A.D. But we need not be so imaginative as that, for sufficient unto the day is the population thereof.

This seemingly rapid growth of India's population is in sharp contrast to the growth of population in some countries of the European and American continents, where the population either has been growing slowly or is stationary or showing a tendency to decline. For instance, the situation in the United States of America is in sharp contrast to the tendency in India. "If the birth rate of the United States should continue to decline as it has during most of the present century by about the year 1975 (just twenty-five years hence) there would be no babies born at all."[1] But we need not be so unduly pessimistic, for the present torrent of babies seems to be well-nigh a war boom and conditions such as this may be expected to take care of the dismal prospect of no babies being born at all at some future date. And nobody need worry that this nadir in the birth rate of the United States or any other country, and much less India, will be reached.

[1] H. P. Fairchild, *People*. p. 1.

GROWTH OF POPULATION

Let us look into the growth of India's population from the times when only rough estimates were possible down to recent decades when a fairly reliable census count has been made possible. In the sixteenth century, India's population, according to some rough estimates, was nearly 100 millions. In the middle of the nineteenth century, the figure reached about 150 millions. In 1881, when the first regular, though incomplete, census was taken, the population stood at 254 millions. In 1931, fifty years later, the population was 353 millions, according to the census report, which represented, incidentally, an increase of 10.6 per cent. over the figure of 1921. The figure of the eighth decennial census of 1941 was 389 millions, which is an increase of 50 millions, or 15 per cent., over the 1931 census figure.

Ever since the first official census was taken in 1871, India's population has been growing from decade to decade for several reasons. Since the formation of what was called the Indian Empire as a part of the British Empire and after 1931, the population of India included, besides the geographical India, Burma, which was a province of India, and even Aden, which was classed as a part of the Indian Empire, but excluded the island of Ceylon, the British Crown Colony, immediately southeast of India. However, the Government of India Act of 1935, which came into force in April, 1937, effected the political separation of Burma and Aden from India proper and today's population figure is for geographical India alone. The accom-

GROWTH OF INDIA'S POPULATION IN MILLIONS

Year	Source	Population	Increase due to		Real increase	Increase in %
			Change in area	Better methods		
1600	Moreland's estimate[2]	100	.....	.....	.....	.....
1750	Shirras's estimate[3]	130	.....	.....	.....	.....
1847	McCulloch's estimate[4]	133	.....	.....	.....	.....
1850	Mukerjee's estimate[5]	150	.....	.....	.....	.....
1861	Our estimate	164	.....	.....	.....	.....
1872	1st partial census[6]	206.2	.....	.....	.....	.....
1881	Regular and rather complete census[7]	253.9	33	12	3	1.5
1891	3rd and complete decennial census[8]	287.3	6	3	24	9.6
1901	Census[9]	294.3	3	.....	4	1.4
1911	Census[10]	315.2	2	.....	19	6.4
1921	Census[11]	318.9	.....	.....	4	1.2
1931	Census[12]	352.9[14]	.....	.....	34	10.6
1941	Census[13]	388.8	−14 (Separation of Burma)	.....	50	15.0

[2] Moreland, W. H. *India at the Death of Akbor* (1927).
[3] Shirras, F. G. *Poverty and Kindred Economic Problems of India* (1931).
[4] McCulloch. *Descriptive and Statistical Accounts of the British Empire* (1847).
[5] Mukerjee, R. *Food Planning for 400 Millions* (1938) p. 3.
[6–13] Census Reports of the Government of India.
[14] Up till 1931, the census figures, as already observed, indicate population for both India and Burma. In 1931, the population of India alone was 338.1 millions and the population figure for 1941 is for India alone.

panying table summarizes the growth of India's population from the sixteenth century down to the last eight census decades and presents the percentage of increase for the same period.

The figures of population and the ratio of growth from the above table are summarized below for the regular census years for India proper.

Census year	Population 000 omitted	Increase	
		Net	Percentage
1881	250,125	.....	.....
1891	279,548	22,471	9.0
1901	283,827	4,278	1.5
1911	302,995	19,169	6.8
1921	305,674	2,679	0.9
1931	338,119	32,445	10.6
1941	388,800	50,681	15.0

So India's population today must be about 400 millions—the largest population of any country in the world that has a regular official and periodical census count. Some students of Indian demography have been more than impressed by this "alarming rate of increase," for India is apparently adding the population of a Spain or even a Poland every decade. At first glance, this annual addition of five millions appears proportional considering that India's population is about a fifth of the total world population. As we have seen already, some have been so stunned by this "terrific torrent of babies" that they make us all tremble before the amazingly dismal prospect of having to begin the next century with more than 700 million souls within the geographical confines of India. We can not, of course, possibly foretell what the population of India or any country will be in any distant

future, for we can not foretell possible changes in current trends. But we can tell what the population will be any number of years hence on the basis of current, recent or assumed trends in the birth and death rates and several other factors which affect the growth or decline of a country's population. Therefore, before we allow ourselves to be impressed by these alarming estimates and forecasts, let us look into the causes, nature and significance of this growth. What then does account for this steady increase in India's population?

An Explanation of This Growth

Several factors—sociological, economic, social, political and religious—account directly or indirectly for this growth. The first, though not the foremost, factor is the comparative peace that India has been enjoying for nearly a century. Before the establishment of British rule, no part of the country enjoyed any prolonged period of peace unbroken by wars, pestilence or famine. In fact, these unstable political and economic conditions were partially the result of the British, French, Dutch and Portuguese imperialist-cum-commercial efforts to establish economic and political supremacy in India. What with these foreign invaders' periodical visits to loot India, the native rulers of India easily took sides and the result was civil wars, though they were not as frequent as those in China. But once the British rule was established with force of arms, comparative peace was also maintained, partly by force of arms and partly by virtue of their political ideals. Thus, for nearly a century India has been enjoying peace and tranquillity, if these terms could be defined as the sum total of averted wars.[15] For a long time India has not been a major theater of war and no great portion of her manpower has been lost through wars comparable to what is happening today on several battle-fronts in the world in the second World War.

The second reason, though not a very important one, is the increasing improvement in the census operations of India, which represent a triumph in organization. The 1941 census year has been a "peaceful" year, despite the fact that India was technically a belligerent country. The last census was also significant, for there was full cooperation on the part of the people with the census authorities. This factor of the nominally present divergence between the interests of the people and the Government of India has often been ignored. But this is a very significant drawback, for there has never been in India's history a national or peoples' government at the center. During this last census, everybody made an effort to get into the census schedule. The 1935 Government of India Act has enfranchised more millions. The people who had become politically conscious thought that getting registered on the census schedule was finding a permanent place on the electoral roll. Despite the fact that there was a political deadlock in the country between the British Government and the majority of the popularly elected cabinets in the provinces, there was no major political upheaval in the country to disturb or interfere with the census enumeration. This factor is often ignored, but it is important, for Gandhi's nationwide Civil Disobedience Movement in 1931 interfered with the census enumeration that year to the extent of a recognizable margin of error.

A major factor contributing to this growth, however, is that the last decade has been relatively healthy and even prosperous. On the negative side, no

[15] "We have given India tranquillity and order," the British argue. "But it is the tranquillity and order of the cemetery," retorts Gandhi. Both can be correct, depending upon the particular meaning they attach to these words. In a wide perspective, Gandhi's retort is not without justification, of course.

nation-wide or even province-wide epidemic or any such catastrophe laid waste the country. Nor was there any famine comparable in its rigors to those of earlier decades. New political reforms in the provinces, the provincial autonomy—which transferred a substantial measure of political control to the people's representatives and the formation of popular provincial governments by the Congress Party gave rise to several ameliorative and progressive changes in the administration of the country.

These new measures of the popular governments have left their imprint in several fields for the betterment of the general economic condition of the people, though the provincial governments' capacity for good was suddenly cut short by the declaration of the present war. There has been some improvement in public health measures in most of the provinces. It is true that improved public health policies do not yield immediate and quick returns. While generally they have a delayed effect on the quantity and quality of the people, they have an immediate effect also in the sense of keeping alive persons who otherwise would have died. For instance, if cholera mortality in India has been brought down, it means that not only are so many more people now present in the population but many of these so preserved reach the stage of reproduction in the course of a decade. If a girl or a young woman is saved from a premature death of cholera, it not only means one soul has been saved, for she continues to live, but she is going to add to the population on reaching the period of reproduction. The marked reduction in epidemic mortality in India for the decade under discussion is in sharp contrast to the decade 1921–31 which bore heavily the results of the influenza epidemic of 1918–20, which accounted for the loss of some twelve millions. This factor partly accounts for the growth of India's population.

The regions which have contributed a substantial number to the All-India population have witnessed in the last decade some striking changes toward improved economic conditions. To take but two examples: the Punjab, which was almost a desert some years ago, has been converted into a smiling garden, thanks to the vast irrigation projects that have been brought into existence in recent years. The irrigation development in the Punjab, bringing more land under cultivation, easing thereby the economic tension in the lives of millions, has contributed to an increase in the population not only within its borders, but beyond them as well. The Punjab has contributed to the increase in the province of Sindh (17 per cent.), Bikanir (38 per cent.) and the Bawalpur States (36 per cent.). All these regions carry a considerable Punjab contribution to their population. The second instance is East Bengal. Parts of this region, though not quite desert-like as in the Punjab, were covered with wooded marshes until recent years. Reclamation work, irrigation facilities and the flood waters have brought this region controlled water supply and consequently under the plough. This inundating water not only irrigates the land but also brings new soil and fertility; the floods also scour out channels and drains. These natural as well as man-made improvements have rendered agricultural operations somewhat more profitable. The result is that this region exhibits a high density of population. The heavy increase in population in East Bengal has also contributed to a rise in the population of Assam, Cooch-Bihar and other adjoining areas.

Besides these ameliorative and progressive measures, there are certain sociological factors that partly explain this decennial increase in population. In India, unlike any country in the west, an overwhelming majority of the population is found to be in the married state.

This by itself does not mean much, except that this factor is potentially a favorable one toward increasing the population. Then the common and rather widely prevalent tendency to marry early with a socio-religious sanction behind it has been a helpful factor, albeit limited in its scope, in the growth of India's population.

It may be pointed out here that climate acts as a favorable factor in the growth of a population. In India the girls attain puberty between the ages of twelve and fifteen and, though often physically unprepared, they are physiologically ready to bear children. And cases are not wanting where reproduction has begun at the age of thirteen and fourteen. The Report of the Age of Consent Committee and the All-India Women's Conference Report have estimated that more than forty per cent. of the girls married in India are below the age of fifteen. The girls marry as soon as they reach puberty, begin begetting children early, reduce the period of lactation, thereby shortening the intervals between child-births with the disastrous final result of a premature grave. The very low level of living, the absence of prolonged period of education or training, the existing social attitudes that encourage a large family, the joint family, the want of nation-wide contraceptive clinical service and above all, the psychological reason that encourages every man to look to his wife and sex intimacy as the only relaxation and recreation in an otherwise dull and unexciting life of a relentless struggle to make both ends meet. The very economic instability makes one resigned and fatalistic; thought for the morrow and contemplation of the prospect of a large family are brushed aside. The thought that he can not be worse off than he is banishes all ideas of foresight and control.[16]

How this low level of living, supported by the strict caste system, damages all efforts on the part of the individual to climb up and push on, eventually resulting in a high birth rate, is pointed out by Warren S. Thompson. "In countries like India," he observes, "where capillarity is small because of a rigid caste system, there is no tendency for the birth rate to decline and for population to die out; just as a very solid substance (copper or iron) will prevent any considerable capillary movement in fluids, so a rigid social structure will prevent upward movement in a society and will thus obviate the danger of an individual development becoming so engrossing that the person has not time for the rearing of a family."[17]

A reconciliation with unheard of poverty becomes imminent. All these contribute their share to the higher birth rate and to the growth of Indian population. As for present growth of population, all this is true. We may summarize here the causes that account for the remarkable growth of population generally and particularly in the last two decades:

1. The relative peaceful conditions prevailing in the country.
2. The increasing improvement in the census organization.
3. The gradual improvement in health measures as compared to earlier decades.
4. The control of famines, though not epidemics, and the increased acreage under irrigation.
5. The universality of married state in India.
6. The large percentage of married women to total women in the reproductive group.

[16] Dr. Samuel Johnson's remark as to why people marry is of some interest. Russia being mentioned as likely to become a great empire by the rapid increase of population, Boswell records Johnson as saying: "Why, Sir, I see no prospect of their propagating more. They can have no more children than they can get. I know of no way to make them breed more than they do. It is not from reason and prudence that people marry but from inclination. A man is poor; he thinks, 'I can not be worse, and so I'll even take Peggy.' "—Boswell's *Life of Johnson.*

[17] Warren S. Thompson, *Population Problems* (1942). p. 39.

7. The comparatively early age at which reproduction begins.

8. Ignorance of the existence as well as the unavailability of cheap and reliable contraceptives.

9. The influence on certain Indian social institutions like caste and the joint family on the birth rate. The joint family serves as an incentive to higher birth rate because it does not insist on the economic stability of the husband as a prerequisite to marriage. If the Babu family should survive, many Babu babies should be born!

10. The psychological drive—the incredible poverty and the low level of living which offer no pleasure in life save that of sexual intimacies.

But let us look into future trends. All this may seem that there is nothing to stop this deluge of brown babies. Some have been so impressed with these factors, favorable to growth, that they make all kinds of forecasts of India bursting with people in a few decades! But let us look deeper into some of these vital factors that decide the addition as well as the reduction of India's population. But before we speculate on the possible future growth or static character or decline of India's population, we must examine a few of the chief characteristics of Indian demography.

Universality of Marriage

The major factor of Indian demography is the universality of the married state in India. For the last fifty years, the proportion of the married to the unmarried has not changed and today India has the lowest proportion of unmarried to both sexes. "In 1931, 407 males and 493 females out of every thousand were married; taking widowers and widows, ascetics and mendicants into account, this means that almost every person of marriageable age was actually married."[18]

[18] Gyan Chand, *India's Teeming Millions.* p. 134.

In western countries, romance (you don't marry some one until you are actually in love with him or her), economic considerations, prolonged period of education and training, eagerness for personal and social advancement—all these contribute to postponement of marriage to a comparatively late date. Religion not only does not condemn celibacy, but has a kind word for it. The current social attitudes do not disapprove of those who never enter the married state. So many do not marry just for the sake of marriage. The pressure of these considerations may even and does often result in many remaining spinsters or old bachelors.

But in India there is no chance of love playing any significant part in marriages. Marriages, by and large, are arranged by the parents and the majority are just herded into the married state. Economic stability of the bridegroom has never been a primary consideration in contracting a marriage. Of course, the parents-in-law are anxious to see that the son-in-law is not unemployed, but his unemployment is not a positive disqualification. The resources of the joint family being available for the support of the newly married couple, economic stability of the husband or the couple has never been seriously considered a prerequisite in getting married. Religion does not encourage celibacy, for a Hindu, if he be a strict one, must have at least a son. But it is not really the fear of religious ostracism that is behind this urge to get married. It is the disapproval of society as such that should explain the universal prevalence of the married state.

Sex Composition

The sex ratio has several important socio-economic bearings. Women generally have a lower death rate than men because nature has equipped them better to meet diseases. Organically it is man that is the weaker vessel. So if

women are less than half the total population, the crude death rate of the whole population will be affected unfavorably. The scarcity of women sometimes leads to prostitution and other social problems, though apparently it may seem paradoxical how any society that can not provide mature brides for all its adult men could spare some women for purposes of prostitution.

The following table shows the sex composition of the Indian population for the last eight censuses. This situation in India—the striking deficiency of women—is in sharp contrast with several European countries and the United States, where males are scarce comparatively.

FEMALES PER 1,000 MALES

Census year	1881	1891	1901	1911	1921	1931	1941
Females	950	960	960	950	950	940	930

Relative scarcity of females has been a striking characteristic of India's population within the knowledge of her regular census history. According to the 1941 census, there were only 934 females for every 1,000 males, as compared to 940: 1,000 in the 1921 census. Dr. J. H. Hutton, the Census Commissioner for 1931, observes: "The figures of population of India by sexes show a further continuation of the steady fall in the proportion of females to males that has been going on since 1901. The female infant is definitely better equipped by nature for survival than the male, but in India the advantages she has at birth are probably neutralized in infancy by comparative neglect and in adolescence by the strain of bearing children too early and too often." He also admits the faulty enumeration of females as a contributing cause in giving low figures for the female population, though this source must account for only a very small error.

The figure is for All-India and the sex ratio varies from province to province. The disparity is least in the Madras presidency. The proportion of females to males becomes less as one proceeds from south and east to the north and west of India. Let us look into this phenomenon a little more closely.

Several factors explain this striking paucity of females in the total population. The social attitudes in the country are such that a female baby is looked upon as a liability, whereas the male baby is welcomed as an asset. This attitude arises out of certain obscurantist factors inherent in the Indian socio-economic order. So a girl in her infancy is treated with a wholesome neglect—neglect nevertheless. Care and attention in her upbringing, especially when beset by infantile ailments, are conspicuously absent. Then there is the simple natural fact that more male babies than female babies are born. And why this is so can not be examined here, for this biological trait has some undefined relation with climate, diet, race, social institutions and the pursuit of values.

There are certain regional conditions affecting death rates which afford a partial explanation of this sex ratio. As Radhakamal Mukerjee points out, "In the plague regions of India, the malady appears to bear more severely on females than on males. Similarly, in malaria-haunted zones, malaria appears to exercise a selective lethal influence on women. On the whole, where economic pressure is more severe and the women are exposed to the hardships of struggle with the soil and climate, as in the zones of precarious rainfall, there is a striking and permanent paucity of women."[19]

Early marriages, if not quite child marriages, worsen the initial balance of births in favor of male babies. This early marriage is generally expected to increase the birth rate. On the contrary,

[19] Radhakamal Mukerjee, *Food Planning for 400 Millions*, p. 234.

the effect is often the very opposite. The ratio between males and females in the age group 0–5 is favorable to females, but is gravely upset by early marriages, because of two undesirable features of Indian demography. One is the terrific maternal mortality and the other the ban on widow remarriages. As for maternal mortality, the figure is shocking: "One hundred out of every thousand girl wives are doomed to die in child-birth." On the average, 200,000 mothers die every year during childbirth or from ailments connected with it. More common than this death of young mothers is the death of women during a little later period of maternity—between 25–35. These deaths are brought on by the physical exhaustion, the nervous breakdown which follows in the wake of premature childbearing.

The second major factor that explains the paucity of women is the social ban on widow remarriage. More than 15 per cent. of the women of the reproductive age (15–45) do not generally reproduce, for they lose their husbands long before they reach the end of their reproductive period. This means that about twelve million women do not participate in active motherhood. Some of them do not taste the fruits of sex intimacy at all—for they are virgin widows and the existing social attitudes do not encourage their marrying again! And some of those who have experienced marital happiness are suddenly deprived of their husbands while still young. Their normal physical cravings, whetted by initial and inviting experience, are left unsatisfied. The consequent emotional poverty in the lives of some millions of young Indian women can not be adequately expressed in any sociological terms. A few do escape the social disapproval by indulging in clandestine sex intimacies with men who are not their husbands. But this is quite different from approved prostitution and so, when discovered, the social tyranny that descends upon the erring individual is unbearable. This grave injustice to the normal and healthy development of Indian womanhood serves as a preventive check to the population, by withdrawing potential mothers from participating in reproduction. This institution of "socially sterilizing" the widows results in certain undesirable features in Hindu society. While widows, irrespective of age, are prohibited from marrying again, widowers, of all ages, are permitted and do marry. Now this double standard of morals created and maintained by the Hindu male results in considerable disparity in age between the average married couple. Since most widowers marry and since they can not marry widows, they have to seek wives among girls very much their juniors. If a forty year old widower wants to marry, he can not marry a woman aged thirty, for a woman at that age is either already married and living with her husband, or a widow. He can not marry even a girl of twenty, for she may be already married, due to early marriage. So he will have to marry a girl below twenty, anywhere from fourteen to eighteen. This unequal combination from the point of view of age itself, leads to increasing numbers of widows. For the old husband soon passes away, leaving behind his very young wife, a widow. And she can not marry, of course. In brief, unmarried and widowed Hindu men have to take brides of any age that they can get. Young men of twenty to twenty-one as well as older men of forty to fifty have to choose brides from girls aged thirteen to twenty, roughly. The natural result is that some of these girl brides survive their much older husbands. The paucity of females keeps up the custom of early marriage for girls. Early marriages lead to considerable disparity in age between husbands and wives. This difference in age increases widowhood. Since widows can not remarry, widowhood increases the shortage of eligible brides, which

means, of course, the paucity of females. Thus the vicious wheel whirls on.

Another factor that worsens the situation is the caste system. This institution can not be discussed adequately in this paper, but it must be pointed out here that caste enhances the already difficult situation of scarcity of females. In caste, the field of choice for brides and bridegrooms is definitely limited. In a particular caste it is possible that there may be comparatively more females of the reproductive age than males of the same age group. As men from other castes can not marry these surplus brides, the problem of every adult male finding a bride of a suitable age in his own caste becomes acute.

The caste system affects the situation adversely in another way, also. If we may accept the results of some recent studies, excessive masculinity in the sex ratio of a population group must be taken as a result of inbreeding. Caste, with its insistence on endogamy, promotes inbreeding. This inbreeding partially explains the deficiency of females in the Indian population. Though this phase of the problem has not been examined in detail with reference to conditions in India, it may be a possible explanation

This uneven sex ratio does not make for social repose or communal harmony. Apart from the dysgenic effects of ill-matched marriages, it leads to graver problems. The marked increase in abduction of women—not kidnapping for the sake of ransom money—in recent years, particularly in Bengal and the Punjab, has created one of the disquieting social problems in India, though its gravity has consistently been minimized.

These facts are not new. Every census report harps on the same tune. They are discussed, debated and decried by all enlightened Indians. There are any number of individual social reformers and progressive associations working for the abolition of these evils. But progress has been slow and slender. A great leeway, therefore, has to be made before any substantial results can be achieved.

The Rural-Urban Ratio

A formidable reason why reform has been slow in this direction is to be found in another characteristic feature of the Indian population. It is the rural and urban ratio composition of the Indian population. An overwhelming majority of the Indian people live in about 700,000 villages. This feature of a vast majority being a rural population presents several obstacles on the path of reform. It is true with almost every country that the rural population is agricultural and feeds the nation, but generally enjoys fewer benefits from the governmental services compared to the urban population. In towns and cities people follow non-agricultural and money-making pursuits like industry, commerce and trade and liberal professions and have ready access to comforts, conveniences and luxuries that are beyond the reach of the rural population. Whoever has heard of an agricultural millionaire living a life comparable in any way to that of an urban industrial magnate? Even from a broad cultural point of view, a nation's political, social and educational movements that constantly stir the people into thought and action center around the cities. Most of the nation-building services are concentrated in the urban areas. Large general hospitals, specialized and advanced clinics with the latest equipment, universities, colleges and seminaries, recreational facilities like parks, sports, games, swimming pools and public utilities like gas, electricity and water—are all within easy reach of our city population.

The Indian census, unlike the American census, makes no clear-cut definition of an urban area. In most cases the decision is left to the superintendent of the census districts. But it is usually taken that a rural area is one whose

population does not exceed 5,000. Villages which have a population of more than 5,000 people are classed as towns and towns with 100,000 or more inhabitants are termed cities. The following table reveals how little progress has been made toward urbanizing India:

THE RURAL-URBAN PERCENTAGE OF POPULATION OF INDIA

Census year	Rural	Urban
1872	91.28	8.72
1881	90.59	9.41
1891	90.54	9.46
1901	90.21	9.79
1911	90.65	9.35
1921	89.70	10.30
1931	89.00	11.00
1941	Figures not available.	

IMMOBILITY OF THE POPULATION

Several factors, social, economic and religious, distinctive of Indian economy, can be cited to explain not only the meager growth of cities but also the existence of comparatively few towns and cities in India. The most striking explanation of this phenomenon is, however, to be found in the general immobility of the Indian population. In no other country is the population so immobile as in India. The comparative stay-at-homeness of the Indian people is a regular feature of many an Indian Census Report. In all censuses, nearly ninety per cent. of the people have been enumerated in districts in which they are born. Another five per cent. is enumerated in adjoining districts which are more industrialized or urbanized than the district of their birth. In 1901, only 9.27 per cent. of the total population was enumerated outside the district of birth. In 1911, this percentage fell to 8.7, and in 1931 the ratio was repeated. Though exact figures are not yet available for 1941, there is no reason to expect any radical change, for during the last decade there has been no significant inter-provincial migration. The volume of such migration that has taken place is so small that it hardly affects the above ratio.

The economic reason for this immobility is simple. As the majority of the people are wedded to an agricultural life and since land is the chief source of sustenance, the average Indian can not possibly leave the farm on which he was born and wherein he works. It is not that agriculture in India is such a paying proposition that it renders rural exodus impossible, but the absence of a better calling to take its place. In India, agriculture is not just an occupation; it is a way of life. Then there is an incredibly large rural indebtedness that chains the peasants to their mortgaged homesteads. Even if the average agriculturist is ready to forsake his traditional calling, what alternative is there for him to make a living? Availability of, as well as adaptation into, a new vocation is neither easy nor smooth.

Certain social factors also contribute to this essential home-loving character of the Indian people. Caste and other social institutions render severance from home village or town uncomfortable. Migration to another province or even to a city may mean an unfamiliar life among people—albeit Indians—who may speak a different language, eat a different kind of food and have different habits and customs.

Finally, migratory tendencies are exhibited largely in small units of population. The smaller the unit of population, the greater the proportion of persons born elsewhere. The fact that India shelters nearly a fifth of the human race militates against any free mobility of the population, though this may seem paradoxical.

LITERACY

What about the educational composition of this population? We can not go into this question of education at any length. We can only touch the problem of literacy in India. What with the

great majority of the population being rural and with the absence of a national network of rural schools, the problem of literacy in India has proved to be a formidable one.

A proper comparison of literacy figures must be based on specific age groups. Infants and children up to four or five years must be excluded in any calculation of literacy figures. What is more, the real task ahead of any country is to make at least all new arrivals literate and to ignore those above fifty or sixty years of age who are illiterate. But such calculations are not possible with the limited data of age groups that are at our disposal for the present population. For the total population as a whole, however, the percentage of literacy has been improving. There were only 80 literates per 1,000 in 1931, as against 120 per 1,000 according to the 1941 census. Literacy has been defined by the Indian Census Authorities as the ability to read and write a post card in one's mother tongue. This increase in literacy is noticeable particularly in Bombay, Central Provinces and Travancore. This figure of 12 per cent. literacy does not show the differences between males and females in this regard. Male literacy has always been higher than female literacy in India. In the 1941 census, the gross figure of 120 literates for every 1,000 of total population is made up of components of the order of 195 for men and 52 for women.

Let us look at this Indian progress in a world setting. Half of the human race, that is, considerably more than a billion people, can neither read nor write. About a third of these illiterates are under the Union Jack in India. The percentage of literacy in India, of course, seems to show gradual increase from census to census. Between 1921 and 1931, she gained one per cent. of literacy and between 1931 and 1941 she gained four more per cent. But the present figure of 12 literates per 100 is really not an improvement, if we forget percentages and look into total figures. In 1931, in round figures, we had 23 million literates (23,484,200) and in 1941 the number rose to 47 million (47,322,700). That is, during the last decade, 23 millions more were made literate, showing a flattering increase of 101.5 per cent. But the illiterates increased, too, and more so than the literates. In 1931, we had 315 million illiterates and in 1941 the figure rose to 341 millions—despite the percentage increase in literacy. The simple answer to this is the high birth rate and the absence of concerted measures to make the people literate. Roughly, India must make 35 millions literate within a decade if she wants to keep up with her birth rate. In other words, India must make 3.5 millions literates every year to hold her own, but actually only about a million become literates. We can not stop the growth of population, nor is it advisable merely on this score. We must have more schools and teachers to take care of the new arrivals, at least.

We need not go into any elaborate comparison of literacy figures between India and other countries of the world. But we must point out what has been achieved elsewhere among conditions that were comparable to India's. Between the two World Wars, Russia has taken magnificent strides in this respect. Under the Tsarist Russia, before the end of the last war, 78 per cent. of the Russian population was illiterate. To-day, twenty-five years later, in the Soviet Union less than eight per cent. are illiterate. The American rule in the Philippines has an equally good record. In forty years of American rule in those islands, illiteracy was cut down from 98 per cent. to 45 per cent. India, after nearly two centuries of British rule, has made no improvement to deserve the word "progress."

Religious Composition

The proportional strength of the main religions in India—an ordinary feature

of formal demography—has become in recent years a major bone of contention in national political squabbles and even in international political relations. The fact that the people of India profess several religions from Animism to Zoroastrianism often threatens to disrupt Indian political life and encourages separationist tendencies. Today it has almost driven a wedge in an otherwise tolerably homogeneous character of the Indian population. This religious composition has also brought into existence, unfortunately, a pseudo-minority problem. But happily, unlike in Europe and in America, this minority problem is not a racial one. In all democratic countries, political development has been on party government based on political and economic ideologies. Thus, we have communists, conservatives, democrats, laborites, socialists, etc. And a communist or a conservative may be a Catholic, Protestant, Moslem or agnostic. In India, unfortunately, political parties (except the leading, progressive and representative Indian National Congress) are based on religious affiliations. Thus, some Moslem democrats, socialists and communists are encouraged to get together into a political party, like the Moslem League. Some Hindus of all economic and political ideologies get together and call it the Hindu Mahasabba. These religious parties go on proliferating into further groups on principles that will amaze any political scientist. This reactionary feature of Indian political development has gathered strength in recent years to the extent of threatening the very geographical unity of India. Several historical-cum-cultural factors can explain this obscurantist development. A future historian may speculate on apportioning the blame to the British government in India, separate electorates, communal franchise, intransigence of certain Indian political leaders, economic tension, cultural conflict down to a mere fight for jobs. Unfortunately, a detailed study of this fascinating but painful subject is beyond the province of our discussion. This has been said because to the average western reader, the question of religious composition of the Indian population is inextricably tied up with the Hindu-Moslem problem, Hindusthan vs. Pakisthan and other -stans and a score of other minor maladjustments of Indian political development.

Apart from this artificially injected political import, the religious makeup of the Indian population is of some interest from a demographic point of view. Different religious groups may have different differential birth rates. Differences in religion may mean in some countries differences in language and even nationality, though this is not true of India. Educational levels, economic security and occupational distribution may be explained to a limited extent on the basis of religious differences. Several interesting questions may be explained in terms of the religious composition of a particular population unit. Why do the Hindus and Catholics have a higher birth rate? Why do the Moslems dominate the hides, skin and leather industry? Why do the Parsees have the higher percentage of literacy and have the highest percentage of population supported by industries? Why are the Sikhs such good fighters and skillful mechanics? All these questions may be answered from a religious point of view alone.

A study of the last six census returns reveals that roughly out of every hundred persons in India, 68 are Hindus, 22 Moslems, 3 Buddhists, 2 Animists, 1 Sikh and 1 Christian. Of the remaining three, one may almost be a Christian, the other on the verge of being a Buddhist and the third probably a Jain. The following table gives the percentages of population that profess the chief religions of India.

RELIGIOUS COMPOSITION

Religion	Percentage						
	1881	1891	1901	1911	1921	1931	1941[20]
1. Hinduism	74.3	72.3	70.4	69.4	68.6	68.2	65.7
a) Buddhism	1.4	2.5	3.2	3.4	3.4	3.7	2.5
b) Jainism	0.5	0.5	0.5	0.4	0.4	0.4	0.4
c) Sikhism	0.7	0.7	0.8	1.0	1.0	1.2	1.1
2. Islam (all sects)	19.7	20.2	21.2	21.3	21.7	22.2	24.2
3. Christianity (all denominations)	0.7	0.8	1.0	1.2	1.5	1.8	1.4
4. Others	2.7	3.2	2.9	3.3	3.1	2.5	4.7

[20] Based on provisional figures only.

WHAT OF THE FUTURE?

What is likely to be the future growth of this population? Will it continue to grow, or remain stationary or tend to decline?[21] On certain assumptions and on the basis of current trends, forecasts may be made on the probable population figure say in 1951, when the next census is due. But such a forecast is unnecessary for our purpose here. We discussed in the foregoing pages certain major features of Indian population and any peep into the future must be based on the realization of the importance of these features. Whether these factors are desirable or undesirable need not detain us here. We take them such as they are, as demographic facts. We have not made any detailed examination of crude or corrected birth, death or survival rates. Nor have we discussed the age composition of the population or the net reproductive rate. All these are beyond the limited scope of this paper. But on the basis of the chief and somewhat unique features of Indian demography we can draw certain inferences not of present trends but of future growth. In drawing such an inference, we must recall that:

1. The majority of the population is rural.
2. The married state of the adult population.
3. The paucity of females and the decreasing proportion of women to the total population.
4. The relatively smaller number of women at the reproductive age.
5. The low specific fertility of these women.
6. The large number of widows who are not expected and do not generally remarry.
7. The high birth rate and the high death rate and the unsatisfactory condition of Indian public health.

These do not reveal a desirable state of affairs, but we are interested here only in the influence that these factors will exercise on the future growth of Indian population. The rural population groups have generally a higher birth rate than the urban population groups. The second factor of every adult being married is favorable to higher birth rate. These two factors will tend to increase the birth rate. But the cumulative effect of these two factors are more than balanced and even nullified by the other factors, which need no elaborate comment. Before we dream of a devastating torrent of babies flooding the finite Indian countryside, we must grasp the significance of these factors.

[21] An excellent discussion of some aspects of this question may be found in P. M. Lad on "Population" in *Economic Problems of Modern India*, ed. R. Mukerjee.

BOOKS ON SCIENCE

THE FAMILY ALBUM[1]

A POPULAR account of the heredity of normal human traits might very well, like this one, be organized about a collection of photographs of the individuals of some three or four families over several generations. Such a collection would be particularly valuable if the pictures were taken with that object in mind. Naturally, such an undertaking would have to be cooperative and would extend over several lifetimes.

The alternative, adopted here, is to make a collection of such material as happens to be available. This has been done with a great deal of persistence and skill, and undoubtedly many a reader will find the book of absorbing interest. A wide range of human variability has been covered. This method, however, has the inherent disadvantage that such a collection of photographs, however excellently enlarged and reproduced, will often fail to depict clearly many of the individual's traits that we would like to know. Nor can this defect be remedied, as seems to have been attempted here, by using the same photograph, or enlarged portions of it, over and over. Indeed, little seems to have been gained (except expense) by reproducing a single portrait ten times and another thirteen,—and these two examples are by no means solitary instances—unless it be that the reader comes to recognize certain visages as old acquaintances. Lack of color in the illustrations is another drawback. One must wonder about the assurance with which the eye color of a man who died in 1857 is said to have been homozygous blue. Nor can photographs depict either a musical voice in father or daughter, or superior literary expression found over three generations in one family, or religious zeal manifested in four, although the photographs of these individuals are all reproduced.

Most geneticists will probably feel that the effort to make the subject simple has been carried to the point of vagueness and inaccuracy. Since the exact mode of inheritance is known only in occasional instances, the author is generally reduced to a statement that a trait is passed down from generation to generation, or that it appears to be dominant or recessive, or inherited in a complex fashion. This mode of treatment becomes questionable when we pass to temperamental characteristics, such as love of nature, orderliness, efficiency, and good taste in dress. Although the role of environment in affecting such characteristics as these is mentioned frequently, the impression nevertheless remains that, because they can be shown to run in families, they are to be considered inborn. "Good taste in dress, as well as ability to draw and paint moderately well seems to be inborn" (p. 206). Real evidence that traits of personality may be inborn is not presented here; nor is it emphasized with sufficient force that the recurrence of a trait in a family is quite as likely to result from family traditions and influences or from the effect of a shared environment as from common genetic factors. Pellagra, too, may be shown to run in certain families whose members share an inadequate diet.

One lays aside the book with mingled interest and regret—interest kindled by the portrayal of the common kinds of variability to be found in even a very few families; and regret that our present knowledge of human genetics and the limitations imposed by the reliance on donated photographs leave us with so little of definite value.

H. B. GLASS

[1] *Family Treasures.* David D. Whitney. 299 pp. $3.50. Jaques Cattell Press.

MODERN METEOROLOGY

In these days when most meteorology books for budding aviators are written by amateur meteorologists who have done some flying and taught all phases of aviation, it is refreshing to find an elementary book on the subject written by a professor of meteorology (Imperial College, London). Though the book is written chiefly for R.A.F. cadets, it is a useful introduction for persons having different ultimate applications. The illustrations are, naturally, taken mostly from Britain, which reduces its usefulness for American readers who are not going to northwestern Europe. Still, the principles of meteorology in Britain hold also in America!

Professor Brunt caters to the elementary and more advanced student by listing at the beginning of the book certain pages and lines that the nonmathematical reader may omit. So skilfully is the book written, however, that the omission of these pages does not break the continuity.

The content is an inclusive coverage of modern meteorology: British type of observations and instruments; variations with time of day and with height; average conditions over the globe—general circulation; elementary physics of the atmosphere; the upper air; radiation; water vapor, condensation, precipitation; clouds; visibility; synoptic charts; the typical frontal depression; nontypical disturbances. Each chapter is closed with a few exercises which, however, ask for facts rather than for reasons.

The elementary physics of the atmosphere is stated so clearly and precisely that it is a pleasure to read such statements as: "Air is said to be *saturated* when it would remain unchanged if it were placed above a plane surface of pure water at its own temperature."

[1] *Weather Study.* David Brunt. Illustrated. xi + 215 pp. $2.25. 1942. Ronald Press Company.

Equilibrium is illustrated by a marble: in a bowl, for stable; on an inverted bowl, for unstable, and on a horizontal table, for neutral.

The author takes certain liberties with the International Cloud classification, notably bestowing on the new "Nimbostratus" the old confusing definition of "Nimbus" that was abandoned by the International Meteorological Organization. Nimbostratus is the cloud or sheet of falling precipitation itself, not the cloud from which it comes. It is pleasing to find information on the effect of precipitation and of different clouds on visibility, and a distinction between visibility from the air and that from a point on the ground.

While it is hardly worth while mentioning a number of points a meticulous meteorologist might wish to see corrected, one can not pass over the two maps of the prevailing winds over the globe in January and July. The winds here depicted do not correspond to the pressure distribution nor to the descriptions in the text. We are surprised to find on the July map: that the prevailing wind over all of North America south of latitude 55 is northerly; that the winds of northern China are also northerly; that the wind sweeps from the Arabian Sea across the southern tip of South Africa and the South Atlantic into South America, blowing much of the way from low toward high pressure. Instead of the prevailing westerlies, all winds south of latitude 35 S are southeasterly, also from low toward high pressure.

The book is recommended to American readers chiefly for the fine presentation of meteorological physics, especially of moisture in the atmosphere and of radiation and its manifold effects. These are the subjects of the author's chief contributions in his comprehensive book *Physical and Dynamical Meteorology.* Also they are least marred from the American point of view by the differ-

ences between British and American techniques. The whole book is a well-rounded unit, nevertheless, and well worth reading for a moderately thorough understanding of meteorology in both its scientific and practical phases.

CHARLES F. BROOKS

MAN'S BEHAVIOR

No field of medicine or of human behavior is so surrounded by prejudice, misconception and ignorance as that part having to do with mental disorder. Not only is ignorance as such lamentable, but in this case it interferes as well with the welfare and happiness of untold thousands. For that reason, Doctor Zilboorg's present volume, a clear and authoritative statement of the nature of mind and its vagaries, serves a most useful purpose.

The author is a prominent New York psychiatrist, an author and medical historian of note, a medical man of wide and deep experience, training, and humanity. He speaks with authority and with a polished literary style.

His first chapter (a long one!) he devotes to certain misconceptions, very properly pointing out, in the words of Artemus Ward, that "ignorance does not mean not knowing but knowing so many things that aint so." He discusses the reasons for some of these misconceptions, such as that the neurotic is a weakling, that mental disorder is shameful, that the only real illness is a physical one, that mental disorder is always due to a bodily malfunction, or that all that the incipient psychotic need do to recover is to "get a grip on himself." He defines his terms, emphasizing particularly that the psychiatrist is a specially trained physician, and that psychiatry, though young by comparison, is a specialty of medicine.

He then proceeds to consider the instincts and their manifestations, the role of the unconscious in the causation of mental disorder, the aims of psychotherapy, and the various ways in which aggressiveness is manifested. In a stimulating chapter on "Crime and Judgment" he discusses the reasons for our vindictiveness toward the criminal in relation to the old principle of "noxal surrender." The final chapter, on "Psyche, Soul and Religion," is a clear exposition of the relationship of psychoanalysis to religion. Here Doctor Zilboorg demonstrates the falsity of the loose charge that psychoanalysis is anti-religious and that it denies free will in the theological sense; psychoanalysis deals with the psychic apparatus, not with the soul.

The book is a valuable contribution to the growing literature on that ceaselessly interesting topic, man's behavior. It should be read by every intelligent person who is interested in himself and the rest of the human race.

WINFRED OVERHOLSER

[1] *Mind, Medicine and Man.* Gregory Zilboorg, M.D. 344 + vi pp. $3.50. 1943. Harcourt, Brace & Co.

THE VICTORIES OF MILITARY MEDICINE[1]

THE technology of warfare has made obvious and fairly well-known advances on all fronts. Modern planes, tanks and bombs make the destructive power of modern armies immensely greater than ever before. Many of us have some near one exposed to the terrific fire power of our enemies, but few realize how the constructive part of the military armamentarium has kept pace with the rapidly changing methods of warfare. Military medicine is a distinctly specialized field of medicine, although it obviously utilizes and applies to its particular problems the advances of civilian medical science.

A new and extraordinarily well-written book presents an inside view of most of the recent advances of military medicine. It is an extremely stimulating text, enlivened with dramatic but never

[1] *Miracles of Military Medicine.* Albert Q. Maisel. 1943. $2.75. Duell, Sloan and Pearce, Inc.

wildly sensational incidences of the healing power of modern military medicine. The author frankly admits that by the time his manuscript got to press it was probably out of date in certain aspects, for the immense research resources of the United States and our allies have concentrated their efforts on problems of urgent military importance. Thus it is not the fault of the author that in a book still damp from the presses, several significant advances have been omitted. Among these are very recent studies on the mechanism and prevention of blast injuries (aerial blast and under-water concussion), the application of crymotherapy in the transport of wounded and the remarkable Stader method of fracture fixation.

Quite rightly, the history of the development of modern methods in the treatment and prevention of shock is given primary position. Shock was probably the cause of more deaths in World War I than any other single complication of injury. The dramatic story behind the development of blood transfusions and later the use of concentrated plasma, which may be collected and stored months in advance, is worthy of close attention by any reader who has the slightest interest in the efforts to save the lives of our boys. Equally dramatic is Albert Maisel's story of how Dr. José Trueta, a Republican in the Spanish Civil War, proved by an immense series of successful cases, the advantages of the closed plaster cast method of treating compound fractures, first suggested many years ago by the American surgeon, Dr. Winnett Orr.

The medical story of the holocaust of Pearl Harbor is perhaps the high light of the whole book, for here in an overwhelming emergency, the one group that was not overwhelmed were the physicians of the Army, Navy and civilian Honolulu. In this one battle, three most significant advances of military medicine had their baptism and proved their worth: the immense protective value of the sulfa drugs, the life saving power of prompt and liberal transfusion and the value of Moorhead's electro-magnetic locator of foreign bodies.

Also described are modern methods for the treatment of burns, improvements in plastic surgery, advances in brain and chest surgery, the application of local anesthesia and, rather briefly, a discussion of tetanus prevention through toxoid immunization. There is a separate chapter on aviation medicine which hints at much more than it tells, for it is in this field perhaps more than any other, that fundamental progress has been made. There is an excellent description of the very important progress made in the rapid transportation and evacuation of wounded with the minimum of fatigue and exposure.

The author wrote so well that one wishes there were more, especially more on military psychiatry and the truly constructive aspects of military medicine which put and keep our troops at such high levels of health and vigor that their own ability to withstand injury and the rigors of modern blitz warfare is very high. Planned, scientific nutrition, immunization against several specific diseases, wiser anti-venereal disease prophylaxis and pre-invasion epidemiologic studies of conditions in far off places have reduced the military sick list to the lowest in history. In the Spanish-American War we lost more men from typhoid fever than from battle wounds! We also must not forget the difference between preventing a head wound with a modern steel helmet and treating one which might have been avoided. Military medicine's main concern is to keep as many men behind as many guns as many days as possible. Through this comes VICTORY.

EDWARD J. STIEGLITZ

THE PROGRESS OF SCIENCE

APHIDS

APHIDS, also commonly called "plant lice," are among the best known insects in the world, for in spite of their very small size they are extremely numerous and so have attracted the attention of everyone who grows either flowering plants, trees or vegetables.

These insects belong to the Order Homoptera (same or like wings) along with the scale insects, cicadas, tree-hoppers, leaf-hoppers and others. The Family Aphididae includes the many varieties of aphids. When fully grown these tiny, soft-bodied creatures are, on the average, no larger than pinheads, and show more variety in color than any other insects. Although most often green, some are pinkish red, yellowish, black or brown. They live on the sap or juices of plants and feed by thrusting tiny hollow stylets, like miniature hypodermic needles, into the plant cells in order to suck out the sap.

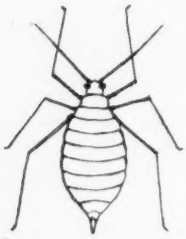
The large numbers of aphids are due to a remarkable reproductive capacity. From eight to ten days after hatching, a female aphid begins to reproduce. This is the shortest life cycle in the animal world, and truly amazing when we compare it to the months and years necessary to produce new generations in larger animals, or even to the weeks necessary for some of the other insects. One aphid may produce from twelve to sixteen young. Each of these begins reproducing in about eight days, thus completing a generation in sixteen days. In Metcalf and Flint's *Destructive and Useful Insects*, we read: "In this way it would be possible, theoretically, for a single female to produce in one year, if all her descendents survived, a chain of aphids long enough to encircle the earth." To appreciate this statement, we must consider a typical life history of these prolific individuals.

When the weather becomes warm enough, aphid nymphs hatch from eggs which have managed to live over the winter. These nymphs, in appearance like tiny adults, are all females which are called "stem-mothers" because they produce great colonies of aphids by the remarkable process of parthenogenesis, bringing forth living young like themselves, without mating. They become "mothers" within a period of less than two weeks, with their numerous children clustered around them. These children are born alive, have only one parent, do not hatch from eggs which have been laid, and are wingless. These, in turn, repeat the reproductive process until many generations have been produced. In these later generations certain ones will grow wings and so can fly to other plants. They, therefore, become known as "spring migrants." These migrants reproduce as stem-mothers starting new generations on new plants and perhaps in new localities. Before the end of warm weather, a generation will be produced which are all winged and are of both sexes, male and female aphids. Being winged, the females (known now as "fall migrants"), often return to the ancestral plants and produce their generations of wingless ovoviviparous young. The young of these fall migrant mothers will not reproduce unless they mate with males of the preceding generation. After mating, the fertilized female lays a few eggs, from one to a half dozen, and then dies. If sufficient shelter for winter protection is provided these eggs they will give rise to the stem-mothers of another spring.

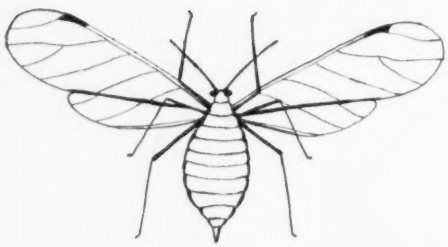
No one has a kind word for the

aphids. They are major pests in gardens, orchards and greenhouses, often occurring in such large numbers as to cause serious damage, if not death, to many kinds of plant life. It is claimed

Aphid in feeding position
Note long beak for sucking
(Greatly enlarged)



Wingless adult aphid
(Very greatly enlarged)



Winged adult aphid
(Very greatly enlarged)

that they are held responsible also for some bacterial and fungus diseases of plants which find a good medium in the sticky honeydew secretion from the aphid's body.

Nicotine used as a dust, or in solution as a spray, is most commonly used in aphid control. This and other means of ridding plants of them are to be found in literature on pest control. Their soft bodies can be destroyed only by a substance which comes into contact with them since they are sap feeders and plant sap can not be poisoned.

There are some insect relatives, however, who could put in a good word for aphids. These are certain of the ants, bees, wasps and flies which feed on the secretions of aphids. Some ants are said to protect and care for them in order to eat the sweet honeydew secretion which the aphids offer. It is claimed that ants may carry young aphids in their mouths not only into their tunnels but to the plants on which the aphids can feed. They are repaid for their work by being fed. This honeydew secretion is recently discovered to be an extract of the juices which the aphids suck from the plants, is passed through the digestive tract and deposited on the leaves and twigs. Being largely cell sap it is good, nutritious food for the insects which have found it.

In contrast to this mutual relationship of ants and others with the aphids is the destruction of them by other insects. Among the aphid colonies may often be seen some ladybird beetles, lacewing fly larvae and perhaps maggots of the bee-like fly Syrphus. These, when present, are there to feed on the aphids.

It is a pity that such insects as these, and so many others, must be looked upon by mankind with anything but interest, for their life history is one of the most amazing and puzzling in the world of nature. We are not all in a position to know and to appreciate the intimate lives of insects. I like them, but I don't encourage the aphids on my tomato plants because of this interest!

SIBYL A. HAUSMAN

CHEMICAL ELEMENTS NECESSARY FOR GROWTH OF ASPERGILLUS NIGER

INVESTIGATIONS in the Bureau of Plant Industry of the U. S. Department of Agriculture, under the direction of Dr. Robert A. Steinberg, on the mineral nutrition of a mold, *Aspergillus niger*, have proved of general interest. It was known, when work was first begun over twenty years ago, that this fungus would grow in sugar solutions containing ammonium nitrate, potassium phosphate and magnesium sulfate. An apparent necessity for minute traces of iron and particularly zinc was questioned, however.

Heating the sugar solution with calcium carbonate followed by filtration was found quite effective for the removal of the last traces of iron and zinc present. The results on growth left no doubt that both iron and zinc are of utmost importance in the nutrition of the mold.

Further studies have revealed the necessity of minute traces of other of the chemical elements. Claims by other investigators of the need for copper and manganese were verified under conditions of rigid control.

Later studies have shown that molybdenum and gallium are also essential for nutrition of Aspergillus. The former element was found to be associated with the capacity for nitrate reduction. It was in this connection that a study of nitrogen supply was undertaken and ammonium found to be the form of inorganic nitrogen converted into organic nitrogen.

The mold does not appear to need calcium, boron, sodium, chlorine or iodine. These elements, with the exception of boron, are required by animals. Green plants require calcium and boron.

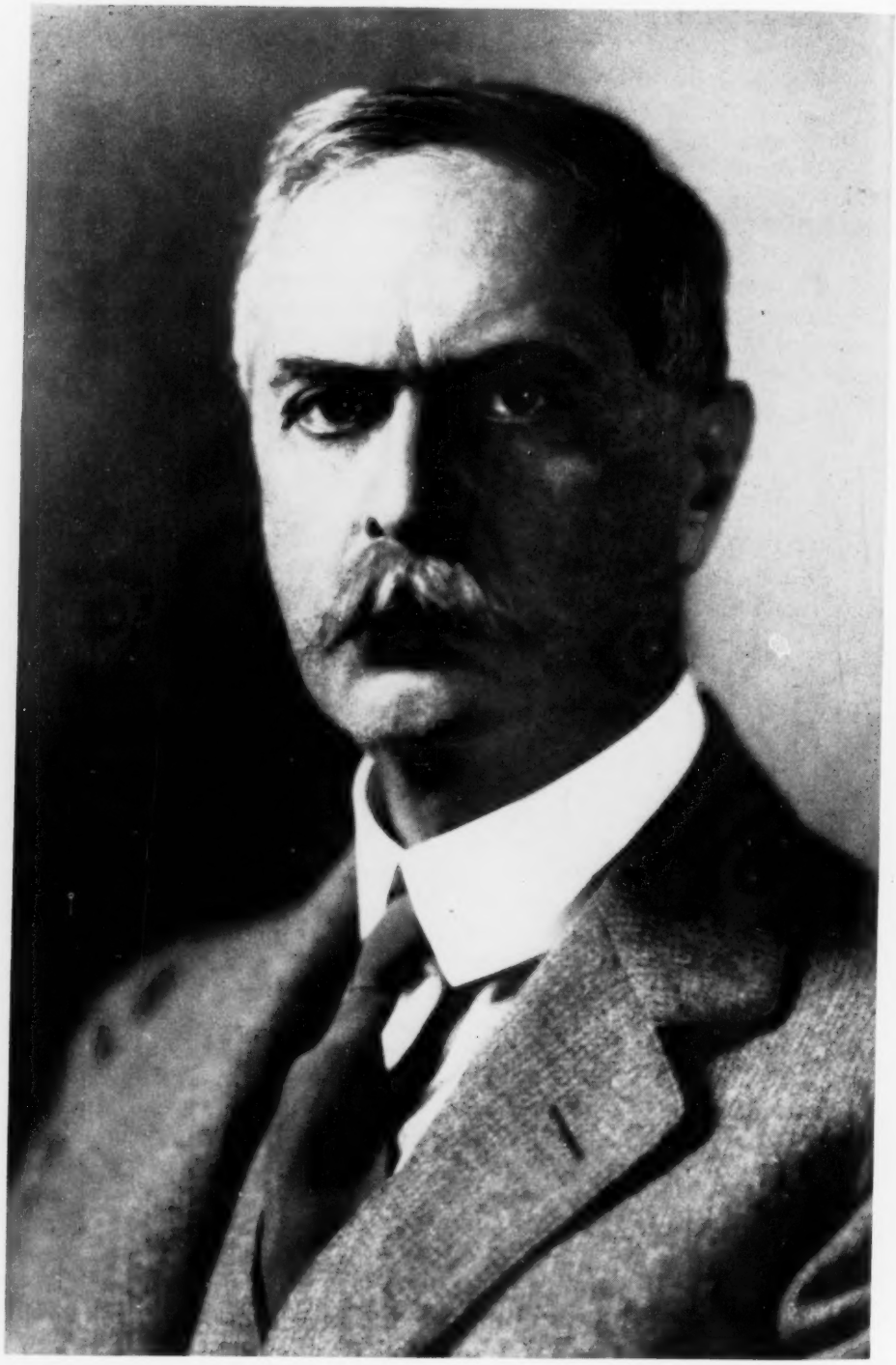
Precision of experimental results has been emphasized. Results in successive experiments have been duplicated to ± 5 per cent. Almost half the values are within ± 1 per cent., a high standard of accuracy in biological studies.

The results of these studies are summarized in a new chemical periodic table based on the data of electronic research. Both electron number and arrangement are considered, and not electron number alone as in the standard table. Each of the 92 chemical elements has a specific position, whereas the positions of 24 elements in the standard table are indeterminate. Other important features are also claimed.

The most important claims that definite regularities occur in the positions of all the biologically essential elements in this table, whether required for plant or animal. These correlations between essentiality and atomic structure lead to the conclusion that essentiality is a property of atomic structure.

Four vacancies occur in this table which it is believed should be occupied by elements not yet proved to be essential. Scandium, it is suggested, may be one of these. The second vacancy would indicate the essentiality of either titanium, zirconium, cerium or thorium; the third of vanadium, columbium, tantalum or protoactinium, and the fourth of nickel, palladium or platinum.

Experimental evidence that elements belonging to the vacancies are essential would be final proof, it seems probable, that the necessary elements are a correlated group and not a random selection. Since the chemical and physical properties of the elements are functions of atomic structure, it is not strange that those necessary for protoplasm are dependent for their biological properties upon the same structures. The atomic correlations of the biologically essential elements are an indication of their completely correlated and mutually dependent functions in the cell. This interpretation is in agreement with the facts of biological specificity of the elements, and the complete destruction of the organism in the entire absence of any one element.



DR. KARL LANDSTEINER

DR. KARL LANDSTEINER

On June 25, 1943, the world lost a great mind and a great medical scientist when Dr. Karl Landsteiner succumbed to a heart attack. Stricken while at work in his laboratory at The Rockefeller Institute for Medical Research, he died two days later at the Rockefeller Institute Hospital. He had just passed the seventy-fifth birthday of a lifetime devoted to fundamental research, whereby he founded and played a guiding role in the development of several important branches of immunology. He had just completed the preparation of a new edition of his book, already a classic, *The Specificity of Serological Reactions*, and had also published about three hundred and thirty papers describing the results of his pioneering investigations.

Dr. Karl Landsteiner, son of Leopold and Fanny Hess Landsteiner, was born in Vienna on June 14, 1868. He entered the University of Vienna in 1885, receiving the degree of M.D. in 1891. After a brief period of study with the eminent chemist Emil Fischer, he turned to the investigation of bacteriological and immunological problems, his earliest studies being carried out when he held the position of pathologist at the Anatomical Institute of the University of Vienna during the years 1898 to 1908. The years 1908 to 1919 he spent at the Wilhelmina Spital. Later he transferred his activities to the R. K. Ziekenhuis in The Hague, Holland. At the invitation of the Board of Directors of the Rockefeller Institute, he came to New York in 1922 and became an American citizen shortly thereafter. In 1939, after seventeen years of active service, he was made an emeritus member of the Rockefeller Institute, but he continued working with no less vigor until the day when his last illness overtook him. While in Vienna, in 1916, he had married Helene Wlasto. Besides his wife, he leaves a son, Dr. Ernest Landsteiner, at present assistant resident in surgery at the Peter Bent Brigham Hospital in Boston.

Dr. Landsteiner is probably best known for his discovery of the human blood groups, frequently called the Landsteiner blood groups in his honor. At the turn of the present century, it was recognized that blood from animals of different species can be distinguished by their serological reactions. This led to the abandonment of the use of animal blood for transfusions to man, but the much too frequent fatal reactions following transfusions of blood from man to man remained to be explained. At this time Dr. Landsteiner had just become interested in the problem of the possible existence of individual differences in blood, as well as differences between species. Choosing what appeared to him to be the simplest method of investigation, Dr. Landsteiner cross-tested the sera from individuals in his laboratory with one another's red blood cells and, instead of the minor reactions that might have been expected, found that in some combinations striking agglutination of the cells occurred while in other combinations no effect was apparent. He then established that this phenomenon of isoagglutination was due to two agglutinogens A and B in the blood cells and two corresponding agglutinins in the sera giving rise in combination to the four groups now known as O, A, B and AB. Dr. Landsteiner's discovery made blood transfusion the safe procedure it is today; it has saved the lives of thousands of persons, many of whom never heard of this famous scientist.

Early in his studies, Dr. Landsteiner became convinced that there were multiple individual serological differences in human blood. At the Rockefeller Institute, he resumed his studies on blood and (with the collaboration of Dr. Philip Levine) described three additional ag-

glutinogens of human blood, M, N and P, which, in combination with factors previously described, raised the number of distinguishable classes of human blood to thirty-six. Additional investigations by Dr. Landsteiner and his associates multiplied this figure still further, in particular, his recent description (in collaboration with the writer) of the Rh factor. The Rh factor has been shown to be of importance in certain rare instances of hemolytic reactions following transfusions of blood of the correct group (by the writer), and in explaining stillbirths and a hitherto obscure hemolytic blood disease of the newborn arising from incompatibility of the Rh types of the parents (by Dr. Philip Levine). While this latter work was done by workers who had been associated with Dr. Landsteiner, his inspiration and guidance were in reality largely responsible.

Dr. Landsteiner's discoveries on individual blood differences have found application in forensic medicine for the individual identification of stains of blood and secretions. They have proved significant for the science of human genetics because they constitute the best example of simple Mendelian heredity in man, and for the same reason they may be applied in courts of law when problems of disputed parentage arise. They have also found application in anthropology for investigating racial origins, and in veterinary medicine. As Dr. Landsteiner demonstrated from tests on lower monkeys, apes and man (carried out in collaboration with Dr. C. P. Miller, and later with the writer), the blood tests furnish evidence of biochemical evolution and "seem to agree with the theory that man and apes are descendants of a common stock, rather than that man evolved from one of the apes."

A problem which early attracted the attention of immunologists was the pronounced specificity of serological reactions. Obermayer and Pick, and later Landsteiner, attacked the problem by studying the effect on the specificity of proteins of their modification by various physical and chemical agents. The possibilities of this method of approach were soon exhausted and Dr. Landsteiner then attacked the problem in a different way, by devising methods of coupling simple compounds with proteins by diazotization. Dr. Landsteiner, assisted by Dr. H. Lampl, showed that in this way the protein was conferred with a new specificity which depended on the nature of the group introduced into the molecule. Carrying this work further at the Rockefeller Institute with his associate, J. van der Scheer, he proved that the specificity of serological reactions in general is determined by the chemical structure of the antigen. This important field of immunochemistry, founded by Dr. Landsteiner and highly developed by himself and other scientists, culminated with the preparation (by Walther F. Goebel and W. T. J. Morgan) of artificial antigens which duplicate some of the serological properties of cellular antigens.

Dr. Landsteiner later became interested in the problem of drug allergy and contact dermatitis, a field of considerable importance in industrial medicine. Here the exciting agent is usually a simple non-antigenic chemical or even an element like the metal nickel. First working with Dr. John Jacobs, Dr. Landsteiner devised methods of inducing sensitivity in animals to some of the chemical compounds causing contact dermatitis in man. Then, together with two other colleagues, A. di Somma and Merrill W. Chase, he adduced considerable evidence to show that this depended on an antigen-antibody reaction, and that the exciting agent acquired its antigenic properties by combining with body proteins.

Dr. Landsteiner made fundamental contributions to other branches of immunology, for example, the diagnosis of syphilitic infection. He showed that alcoholic extracts of *normal* tissues contained the active principle responsible for Wassermann's test, an observation on which is based the current use of beef-heart lipids as antigen in the test. He introduced dark-field illumination for the demonstration of spirochetes, and elucidated the mechanism of paroxysmal hemoglobinuria. Dr. Landsteiner also succeeded, for the first time, in transmitting the virus of poliomyelitis to rhesus monkeys, in that way inaugurating the experimental study of that disease.

The fundamental significance of Dr. Landsteiner's discoveries was recognized only gradually even by his fellow-scientists, and honors came to him relatively late in life. In 1926 he was awarded the Hans Aronson Foundation prize. In 1930, he received the Nobel Prize in Medicine for his discovery of the blood groups, and the same year he received the Paul Ehrlich medal for his chemical studies. He was made an honorary member of numerous scientific bodies in Europe as well as in this country; in addition to being made a Chevalier of the French Legion of Honor he was awarded the Dutch Red Cross Medal. At a citation in his honor read on the occasion of the award of the honorary degree of Doctor of Science at Chicago University, he was called, "the world's greatest authority on the mechanism of immunity," and a Harvard citation stated, "he founded a school of thought which has penetrated wherever immunologists are at work."

Apparently unaffected by these honors, modest and kind, Dr. Landsteiner continued his work until the day his last illness overtook him. Dr. Landsteiner's austere life, marked by a continuous series of outstanding scientific discoveries, stands out as a symbol of the progress possible under governments allowing individual freedom and opportunity.

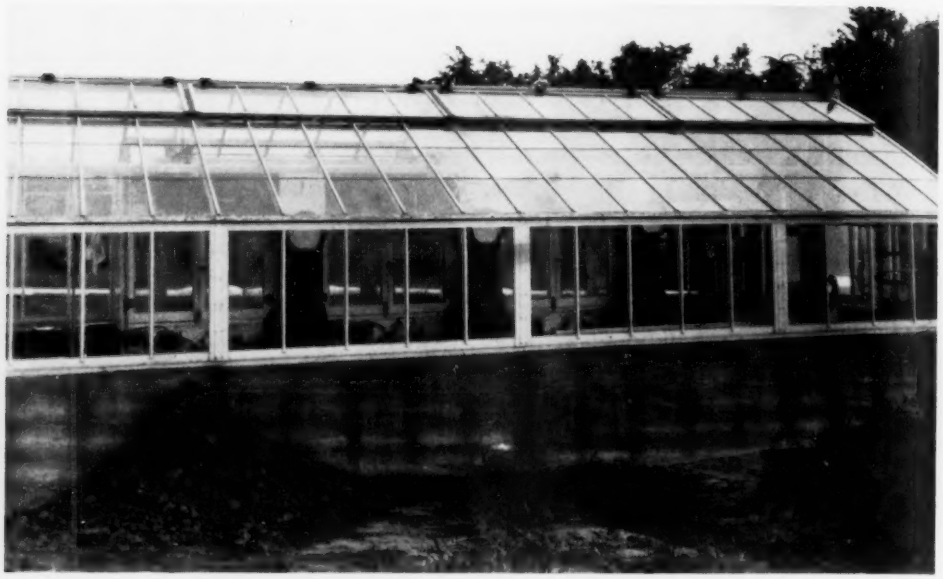
A. S. Wiener

SOME EFFECTS OF SOIL AND AIR TEMPERATURES ON THE GROWTH OF CERTAIN GRASS SPECIES

Since the geographical distribution of grasses as well as seasonal variations in their growth are strongly influenced by temperature, a more thorough knowledge of the temperature relations of some of the grasses would not only contribute toward the solution of some problems of lawn and pasture management, but would also afford a better understanding of the climatic adaptation of the different species. Under natural conditions climatic factors vary together in such a manner that it is difficult to separate their individual effects. Therefore, the relation of the growth of certain grass species to air and soil temperature was determined in thermo-regulated growth chambers.

The growth chambers, of which there were three, were equipped with thermostatically controlled heating and cooling units designed to permit their simultaneous operation at different temperatures. Each growth chamber consisted of a modified soil-temperature tank surmounted by a glass-enclosed compartment, the air chamber, the temperature of which was regulated independently of that of the soil temperature tank. The growth chambers were located within and along the south side of a greenhouse, the long axis of which extended east and west.

Among the grasses investigated were Kentucky bluegrass (*Poa pratensis*), the most important lawn and pasture grass



NORTH SIDE OF GREENHOUSE CONTAINING TEMPERATURE CONTROL UNITS

in the northeastern states; Bermuda grass (*Cynodon dactylon*), the leading lawn and pasture grass of the cotton belt; and orchard grass (*Dactylis glomerata*), a pasture grass which, compared with the above species, is intermediate with respect to its temperature adaptation.

The experimental grass cultures, each of which consisted of 25 plants started from seed, were grown in pots 8 inches in diameter and 18 inches deep. Since each culture was grown for approximately 8 weeks before exposure to controlled temperatures, the grasses studied were relatively immature, but were beyond the seedling stage. The period of exposure to the different experimental temperatures in the growth chambers was also 8 weeks.

Both Kentucky bluegrass and orchard grass made considerable growth at an air and soil temperature of 40° F., the lowest temperature used in these studies. Bermuda grass, on the other hand, not only made no growth but was severely injured by the 40° temperature. The first symptoms of cold injury consisted of a wilting of the leaves as if water absorption by the southern grass were being retarded by the low root and soil temperature.

The production of foliage by bluegrass increased as the temperature was elevated by 10° intervals from 40° to 90° F., although it is probable that the optimum temperature for top growth lies somewhere between 80° and 90°. The optimum temperature for root and rhizome growth, however, was 60°. At an air-and-soil temperature of 80°, root growth in the lower soil levels—8 to 16 inches deep—was almost completely suppressed, and at 90° there was no increment in the dry weight of roots. Therefore, the depressing effect of soil temperatures of 80° or above on the growth of Kentucky bluegrass observed under natural conditions is probably due largely to the retarding effect of the super-optimal temperature on root growth.

The optimum temperature for top-growth by orchard grass was 70° F.,

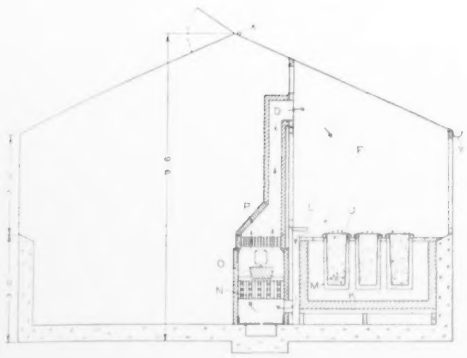


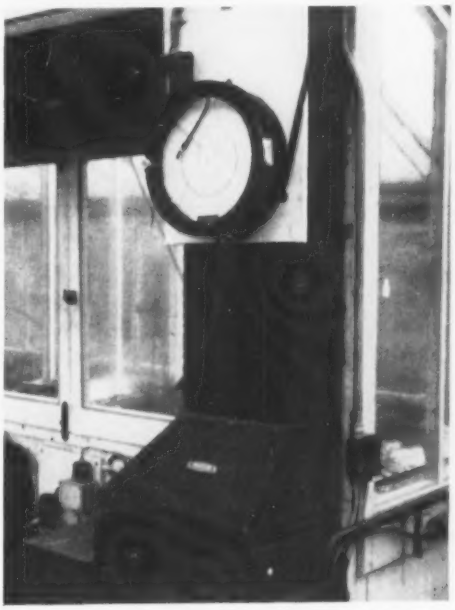
DIAGRAM CROSS-SECTION

OF GREENHOUSE AND TEMPERATURE CONTROL UNIT. D, AIR DUCT; F, AIR CHAMBER; J, SOIL CONTAINER; K, SOIL TEMPERATURE TANK; L, BAFFLE OVER AIR OUTLET; M, SLEEVE; N, COOLING COILS; O, FAN; P, ELECTRIC HEATER.

although growth within the temperature range of 50° to 80° did not vary much in this species. However, a further rise in air-and-soil temperature to 90° resulted in a sharp decrease in shoot and foliage production by orchard grass. Root growth increased as the temperature rose from 40° to 60° and was maintained with a further elevation to 70°. Although total root growth was less at an air-and-soil temperature of 80° than at 70°, root development in the lower soil—8 to 16 inches deep—was much larger than in the case of Kentucky bluegrass at the same temperature. This difference in root growth at 80° in the lower soil levels may explain the observed fact that under natural conditions the growth of orchard grass is not reduced as much or as quickly as that of Kentucky bluegrass by temperatures of 80° or above. However, at the 90° temperature, orchard grass, like Kentucky bluegrass, made practically no root growth.

The growth rate of both the roots and the tops of Bermuda grass, which made no growth at an air-and-soil temperature of 40° F. and very little at 50°, increased with each 10° rise in temperature to and including 100°, the highest temperature employed. At the latter temperature both bluegrass and orchard grass suffered severe injury. In fact, 95 per cent. of the orchard grass plants were killed by 8 weeks of exposure to the 100° temperature, but less than 10 per cent. of the bluegrass plants failed to recover when removed to a more favorable temperature.

A high soil temperature—100° F.—was much more harmful to bluegrass and orchard grass than a high air temperature. When these grasses were exposed to a continuous air temperature of 100° F. for 8 weeks with the soil temperature tanks maintained at 70°, the grasses not only remained normal in appearance but made some growth.



INTERIOR OF GREENHOUSE

SHOWING TEMPERATURE CONTROL UNITS.

These studies are being continued both in the greenhouse and in field plots.

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POWDER METALLURGY

SCIENTIFIC literature has recently shown revived interest in the oldest art for the production of metallic instruments—powder metallurgy. This is quite natural, for in the last thirty years we have witnessed great strides in the development and understanding of metallurgy and metallurgical processes, as well as in their application in modern industry.

The history of the development of this art is interesting. It began with the Egyptians, as early as 3000 B.C., who left iron instruments made from iron ores reduced to metal by heating in contact with charcoal to incandescence by the aid of bellows. The resulting sponge iron was then hammered while hot into the shapes desired. Such instruments have been examined by modern metallurgical methods and found to be quite free from slag and impurities, and they compare favorably with iron products made by fusion. It must be remembered that there were no furnaces for melting metals at that time and no ceramic materials in which to melt them.

Relics of Ecuador have been examined and found to consist of particles of platinum bound together by gold and silver which form a low melting point alloy. These articles have been assigned to a period dating back before the discovery of America, and were formed in much the same manner as those made by the Egyptians.

During the eighteenth century Wollaston produced platinum from metal powder made by the ignition of ammonium platinic chloride. He placed the powder into a tapered mold and used water to settle the powder so that it would be level and of uniform density. He then inserted a plunger into the mold and applied pressure to the plunger by means of a toggle press, thus forming a compact mass that could be removed from the mold and handled without danger of breaking. It was then gently heated on a coke fire to drive off the moisture. It was next placed on quartz sand, covered with an inverted refractory pot, and heated in a wind furnace for about twenty minutes. The compact mass was removed while hot and hit with a heavy hammer. After this forging action, the metallic particles were sufficiently welded together to permit further working. Even at this late date, there were no furnaces or ceramic materials available to permit the fusion of such a high melting point element as platinum.

It has been only within the past thirty years that Dr. W. D. Coolidge, of the General Electric Company, invented ductile tungsten. E. G. Gilson, of the same laboratory, invented a porous bronze bearing consisting of a mixture of copper, graphite, tin, and sometimes lead and zinc. N. H. Adams, also of the General Electric Company, invented copper-impregnated tungsten used widely as electrodes in spot and line welding. Heinrich Baumhauer and Karl Schroeter, of the Osram Lamp Company, in Germany, developed cemented-tungsten carbide, after which hot-pressed cemented-tungsten carbide was developed in the research laboratory of the General Electric Company, and several other mixed carbides, such as tantalum carbide and tungsten carbide, tungsten carbide and titanium carbide, and tungsten, tantalum, and titanium carbides cemented together with cobalt. Balke, of the Fansteel Company, developed a tantalum carbide material cemented with nickel. George Taylor, of the General Electric Research Laboratory, developed diamond-impregnated, cemented-tungsten carbide for wheel dressers and oil-well drills. Goodwin H. Howe, of the same laboratory, more recently invented the sintered alnico magnet material generally composed chiefly of iron, cobalt, nickel, and aluminum.

All of these materials are made from metal powders pressed together in a

mold to form a compact mass of the desired shape and size and then heated in a suitable reducing atmosphere to bond the particles together.

Recently the automotive industry has developed the use of cheap iron powder in the manufacture of many parts demanding lubrication, such as bearings, washers, cams, oil pump gears and door catches. They have used oil-impregnated bronze bearings for years. This industry is ideal for the application of powder metallurgy, since its product has many small parts that require lubrication. Oil-impregnated bearings can be turned out by automatic machines by the million, sintered in atmosphere-controlled, continuous-operating, automatic temperature-controlled furnaces where the pressed compact goes into one end and the bearing comes out the other, finished except for the oil impregnation. However, in many cases where the tolerances are close, a cold-coining operation is required; that is, a resizing by restriking the sintered product in a die, or a final sizing by finish grinding or machining.

Iron parts to which carbon or graphite has been added may be sintered by heating to a temperature sufficiently high to bring about diffusion of carbon or graphite into the iron-forming steel. Iron may be bound together with copper in the same manner. The parts containing carbon may be heat-treated as are steel articles made from fused metal that has been cast and worked.

Many applications do not require material with high physical properties, but only lubrication to prevent wear. The porosity of the compressed compact is controlled by the amount of pressure applied and the temperature and time of sintering, and sometimes volatile compounds are added to aid in maintaining porosity.

Pressed powder materials with high tensile strength, high density, and greater ductility may be made by heating the sintered compact and applying pressure. This process, however, has a very limited use for much trouble is experienced with seizure in the mold, excessive die wear and die cost.

Pressed powders sintered at temperatures close to the melting point in a suitable atmosphere for a sufficient length of time show strengths comparable to cast materials of the same composition. Compacts of iron, cobalt, and nickel sintered in this manner have been produced with the theoretical densities for these elements. Sintered powder mixtures or alloys have been produced having the characteristics of a casting of the same composition, and when hot-worked, have all the characteristics of a wrought material produced by melting, casting, and forging.

The term *sintering* as applied to powder metallurgy has had various interpretations, but, in general, the meaning of this term is the bonding together of particles facilitated by the application of pressure and heat. Many things happen during such an operation. The microscopic particles of powder on pressing become bonded together by interlocking and seizure. During heating, the small particles crystallize and form grains; then these grains begin to grow, the larger ones absorbing the smaller. During this grain growth, the small particles rearrange themselves, taking on the orientation of the grains which absorb them. Surface tension at temperatures close to the melting point causes the particles to draw more closely together, shrinkage takes place, and the voids between the grains gradually disappear with time until the sintered mass becomes a solid aggregate of grains firmly bonded together.

Powder metallurgy is ideal for mass production methods because with a single die, a pill machine and a suitable atmosphere, temperature-controlled, continuous-furnace small parts can be turned out by the thousands. Elements with

high melting points, such as tungsten and molybdenum, may be sintered and hot-worked at a reasonable temperature into any desired form. There are no ceramic materials in which to hold them even if they could be melted.

One of the greatest advantages of the process is due to the fact that porosity of a sintered compact can be controlled, thus making it possible to impregnate it with oil and use it as a bearing, which, in many cases, demands no additional lubrication.

High melting-point elements or compounds can be mixed and bound together by the fusion of a lower melting element, such as cemented-tungsten carbide or copper-impregnated tungsten. Powder metals and alloys can be pressed to any desired shape and size and sintered without any machining or waste of material. Pure metals can be mixed in any desired proportion and sintered without danger of the contamination that often accompanies melting.

Many small parts, intricate in shape, which would be very costly if made by machining or casting, can be made less expensively by sintering. A casting might be very brittle and non-workable, while the sintered product would be strong and not so brittle. An example is sintered alnico magnet material. The size of sintered articles can be very accurately controlled by a cold coining operation, and sintered metals can be produced with physical characteristics entirely different from those produced by any other method.

There are, however, some disadvantages and limitations to the sintering process. The cost of metal powders is inherently greater than that of metals used for melting, and in some cases many times greater, and the physical properties of sintered materials are lower than those of wrought materials of the same composition. The cost of dies is so high in cases where only a few parts are required that it is prohibitive.

Powders when pressed do not flow around corners as do many plastic materials. On that account the design of the part to be formed is very important. The plungers operate in straight lines, and in order to withdraw the plunger or eject the compact after forming without breakage of the compact, the design of the die and compact must be correct.

Many automatic machines of the pill machine type are used today to turn out small parts. As the size of the part increases, the machine tool cost increases greatly. Many of these large machines are hand operated and the cost of production is greatly increased.

With large parts, the material cost alone in many cases prohibits their use. Large parts are difficult to produce to size and shape due to the non-uniform distribution of pressure in the compact during pressing which results in non-uniform shrinkage and distortion upon sintering.

The present activities of metallurgists and the wide use of money and materials for the further development of this very old art are bound to bring some new inventions, new applications, and further development of the industry. It is not a cure-all, however, for metallurgical and mechanical needs. It fits into its own niche which, in many cases, can not be filled at the present time by any other known process. The industry has become large, the value of a single year's production running into many millions of dollars.

The formation of committees by some of our national scientific societies would be of great service by stimulating interest in the future development of sintering and by supplying the consumer with the much needed information on the characteristics and physical properties of materials made by the process.

F. C. KELLY